Tri-Service Remedial Project Manager's Handbook for Ecological Risk Assessment

February 2000

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TRI-SERVICE REMEDIAL PROJECT MANAGER'S HANDBOOK
FOR
ECOLOGICAL RISK ASSESSMENT

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This handbook is written for the person that manages the Ecological Risk Assessment (ERA) process to ensure that it stays on schedule and meets budget and regulatory requirements. The objectives of this handbook are to give the Remedial Project Manager (RPM) of a hazardous waste site at Department of Defense (DoD) facilities: (1) An overview of the ERA process that complies with current regulations and laws, (2) Listings of when and where to seek technical assistance, (3) A list of Key Terms cross-referenced for use in ERAs, (4) Some "Rules of Thumb" for overseeing ERAs, (5) Internet sites with useful information for performing and managing ERAs. This handbook, written in easy to read format, is an updated summary of the Tri-Service Procedural Guidelines for Ecological Risk Assessments and is designed to help the RPM understand the ERA process. This handbook does not, per se, show the reader how to manage the ERA. However, it can be used by the RPM as a management tool. This handbook distinguishes between the ERA approach used by the Army and Air Force and the approach used by the Navy. Both approaches incorporate procedures from the U.S. Environmental Protection Agency ERA Guidance for Superfund.

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PREFACE

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LIST OF ACRONYMS AND ABBREVIATIONS

AEC	Army Environmental Center
AFCEE	Air Force Center for Environmental Excellence
AQUIRE	U. S. EPA's AQUatic Information REtrieval database
ARAR	Applicable or Relevant and Appropriate Requirements
BAF	Bioaccumulation Factor
BRAC	Base Realignment and Closure
BTAG	Biological and Technical Assistance Group
CAA	Clean Air Act
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
CERCLIS	CERCLA Information System
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
CHRIS	Chemical Hazard Information System
CMS	Corrective Measures Study
COPEC	Chemical of Potential Environmental Concern
CWA	Clean Water Act
DERP	Defense Environmental Restoration Program
DoD	Department of Defense
DTIC	Defense Technical Information Center
DQO	Data Quality Objectives
EA	Environmental Assessment
EC_{50}	Median effective concentration
EEC	Estimated exposure concentration
EIS	Environmental Impact Statement
ERA	Ecological Risk Assessment
ERAGS	Ecological Risk Assessment Guidance for Superfund
FFRO	Federal Facilities Reuse Office
FS	Feasibility Study
HI	Hazard Index
HQ	Hazard Quotient

IRP	Installation Restoration Program
LC_{50}	Median lethal concentration
LD_{50}	Median lethal dose
LOAEC	Lowest Observed Adverse Effects Concentration
LOEC	Lowest Observed Effects Concentration
LOAEL	Lowest Observed Adverse Effects Level
LOEL	Lowest Observed Effects Level
NEPA	National Environmental Policy Act
NFESC	Naval Facilities Engineering Service Center
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NOAA	National Oceanic and Atmospheric Administration
NOAEC	No Observed Adverse Effects Concentration
NOEC	No Observed Effects Concentration
NOAEL	No Observed Adverse Effects Level
NOEL	No Observed Effects Level
NPL	National Priority List
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facilities Investigation
RI	Remedial Investigation
RPM	Remedial Program Manager
SARA	Superfund Amendments and Re-authorization Act
SDWA	Safe Drinking Water Act
SMDP	Scientific Management Decision Point
SWMU	Solid Waste Management Unit
T&E	Threatened and Endangered
TEC	Toxicological endpoint concentration
TRV	Toxicity Reference Value
TSCA	Toxic Substances Control Act
TSERAWG	Tri-Service Ecological Risk Assessment Work Group
USFWS	United States Fish and Wildlife Service
USACE	United States Army Corps of Engineers
U.S. EPA	United States Environmental Protection Agency

TRI-SERVICE REMEDIAL PROJECT MANAGER'S HANDBOOK FOR ECOLOGICAL RISK ASSESSMENT

1. INTRODUCTION

1.1 Handbook Objectives

This handbook is written for the person that manages the Ecological Risk Assessment (ERA). This person may have different titles, and may have other responsibilities, depending on the service (Army, Navy, or Air Force). For the sake of brevity, this person is referred to as the Remedial Project Manager (RPM) in this handbook. The objectives of this handbook are to give the RPM of a hazardous waste site at Department of Defense (DoD) facilities:

- An overview of the ERA process that complies with current regulations and laws.
- Listings of when and where to seek technical assistance (Section 1.6).
- A list of Key Terms cross-referenced for use in ERAs (Section 7).
- Some "Rules of Thumb" for overseeing ERAs (Appendix A).
- Internet sites with useful information for conducting and managing ERAs (Appendix B).

Enclosed, in less technical language, is an updated summary of the *Tri-Service Procedural Guidelines for Ecological Risk Assessments* [1]. This summary attempts to help the RPM understand the ERA process. This handbook is not intended to be policy.

This handbook suggests when and how to contact technical experts to help manage and focus the ERA. Included are some "Rules of Thumb" that the RPM can use to ensure the ERA accurately estimates risk. Also included is an understanding of how ERAs can help RPMs comply with the Comprehensive Environmental Response Compensation and Liability Act (CERCLA, Superfund) and the Resource Conservation and Recovery Act (RCRA). (see Section 1.4).

This handbook is not intended to make RPMs into ERA technical experts. It will not determine the appropriate scale or complexity of an ERA. Specific experimental protocols or methodologies will not be recommended. Such factors will depend on the goals, regulatory requirements, and resources of each site. However, the reader will have a general idea of how to decide when the ERA should continue or end. Tips include why, how, and when to go in certain directions to accurately estimate risk, meet regulatory requirements, and be cost effective. This handbook follows the foundation for ERA protocol described by the U.S. Environmental Protection Agency (U.S. EPA) in *Framework for Ecological Risk Assessment* [2], then revised and refined in *Guidelines for Ecological Risk Assessment* [3], and *Ecological Risk*

Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments [4].

This handbook does not, per se, show the reader how to manage an ERA. However, it can be used by the RPM as a tool to help manage the ERA process. If procedures of this handbook are followed, the RPM should have a scientifically sound estimate of risk that can be used to make management decisions. DoD personnel should follow managerial guidance recommended by their respective service.

1.2 What is an Ecological Risk Assessment?

ERA is the qualitative or quantitative appraisal of the actual or potential impacts of stressors (i.e., contaminants) on plants and animals at a site, other than humans and domesticated species. A good ERA determines if living organisms and/or their environment have been adversely affected, or may be affected in the future due to existing conditions.

As early in the ERA process as is feasible, those involved in the ERA's development should decide what aspects of the environment are valued most highly. Unacceptable changes to the valued aspects of the environment are referred to as adverse ecological effects. Significant adverse effects may trigger a cleanup. The definition of adverse effects will vary with each site; however, it is not always clear-cut. The definition of adverse effects is formulated before the ERA work plan is finalized. All those involved with site management and regulation should strive for consensus on the definition of adverse effects at a particular site.

An ERA then uses information from scientific studies, surveys, and site characteristics to estimate ecological risk. Ecological risk is the probability or likelihood of adverse ecological effects occurring. Ecological risk exists when a stressor (contaminant) is in contact with any part of the ecosystem long enough and at a level that is able to cause an adverse effect. Unlike Human Health Risk Assessments, ERAs usually address risk at the population, community, or ecosystem level. An ecological stressor is something (e.g., a chemical compound) that has the potential to cause an adverse effect.

Rule of Thumb #1

Ecological Risk is **NOT** occurring if:

- The stressor is no longer present.
- The stressor did not/will not contact a susceptible ecological component.
- Contact with the stressor did not/will not occur long enough or in sufficient intensity (e.g., concentration) to cause a negative effect. Indirect effects (e.g., altered wildlife habitats) as well as direct effects should be considered.

Rule of Thumb #2

When no adverse ecological risk exists, the ERA should then stop, even if stressors (e.g., chemical compounds) are present. If land-use dictates that ecological components will not be present, the ERA should not proceed.

ERA activities should:

- Identify ecological risks resulting from point (e.g., landfill leachate draining into a stream) and non-point (e.g., airfield runoff) sources.
- Distinguish between changes caused by chemical releases and those from natural stresses or cycles.
- Be non-destructive to the ecological component or the environment.
- Promote a rapid turn-around from data collection to decisions on status of the environment and remediation.
- Protect the existing biological communities within the larger ecosystem.

1.3 How are ERA Results Used for Management of a Site?

The goal of the ERA is to provide enough information to assist the risk managers in making an informed decision. General management objectives are:

- Identify and characterize current threats to the environment from a hazardous substance release.
- Identify and characterize future threats to the environment from a hazardous substance release.

RPMs can use ERA data to:

- Characterize baseline risk to determine whether cleanup should be considered.
- Determine site-specific contaminant levels that provide adequate protection from unacceptable risks.
- Evaluate remedial alternatives for potential risks of the remedy.
- Determine if the remedy is effectively reducing ecological risk.

Rule of Thumb #3

Criteria for determining "adequate protection" and "unacceptable risks" should be decided by site managers and regulators before the ERA work plan is finalized.

1.4 How does ERA Fit into the Regulatory Context?

This section presents a brief overview of the two primary environmental laws where an ERA is required. All the requirements for investigation and cleanup of potential hazardous waste sites are not listed here.

1.4.1 Comprehensive Environment Response Compensation and Liability Act (CERCLA) and Superfund Amendments and Reauthorization Act (SARA)

The CERCLA/SARA law mandates the protection of human health and the environment. Performance of an ERA is the manner in which both EPA and DoD assess potential risks to the environment and determine the need for remedial action. There are several sections under

CERCLA/SARA that specifically state a requirement that the environment shall be protected; Sections 104, 105(a)(2), 121(b)(1), 121(c), and 121(d).

The implementing regulation that states when and where to conduct an ERA is found in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) under 40 CFR 300. To comply with the NCP and CERCLA/SARA, the DoD shall perform a Remedial Investigation (RI) and Feasibility Study (FS) for each CERCLA/SARA site that does not exit the process after the Site Inspection (SI) phase. The NCP requires that:

- The lead agency (i.e., DoD) shall perform a baseline risk assessment during the RI.
- This risk assessment shall "characterize the current and potential threats to human health and the environment".
- Any remedial action triggered by unacceptable risk must comply with enforceable standards [Applicable or Relevant and Appropriate Requirements (ARARs)], unless the lead agency obtains a waiver.
- The FS evaluates remedial options based on the results from the RI.

Note: There are requirements under the SI to eliminate sites from further consideration if it does not pose a threat to public health and the environment. In some cases, sites can be screened out because risks are negligible.

1.4.2 Resource Conservation and Recovery Act (RCRA)

Sections 3004(u) and (v), and 3008(h) of RCRA require a corrective action program for releases of hazardous wastes or hazardous constituents from solid waste management units (SWMUs) to all media, both on and off the facility, regardless of the time at which the waste was placed in the SWMU. These requirements are imposed when installations request a RCRA permit for Treatment, Storage and Disposal of hazardous waste. In a 1996 proposed regulation on corrective action (61 Fed. Reg. 19431 (May 1, 1996), EPA mentions that some form of ERA will generally be necessary (61 Fed Reg at 19446 and 19451). This proposed rule is analogous in many ways to the National Contingency Plan of CERCLA. An ERA may help comply with requirements of the RCRA Facility Assessment, RCRA Facility Investigation and Corrective Measures Study.

RCRA Facility Assessment (RFA)

RFA is comparable to a Preliminary Assessment/Site Inspection of CERCLA/SARA. An evaluation of the installation is conducted to identify potential Solid Waste Management Units (SWMU) or Areas of Concern (AOC) where a potential release has occurred.

RCRA Facility Investigation (RFI)

If the results from the RFA indicate a release or potential release of a hazardous waste or hazardous constituent from a SWMU has occurred, then an RFI must be conducted. The RFI is a characterization of the site to determine nature and extent of the release, as well as to determine if the release to the environment poses an unacceptable risk. This phase is comparable to the CERCLA RI phase.

Corrective Measures Study (CMS)

The CMS is conducted if the results of the RFI indicate an unacceptable risk exists or could exist. The CMS, which is comparable to the CERCLA FS, evaluates the corrective measure alternatives and establishes remediation goals.

1.5 Natural Resource Trustee Notification

According to Sec. 104(b)(2) of CERCLA, the lead agency shall promptly notify the appropriate natural resource trustees of potential injuries to natural resources resulting from releases of hazardous substances. Notification is necessary to allow the natural resource trustee to take appropriate action, such as conducting preliminary surveys to determine if natural resources have been injured, coordination with the response agency, assessment of damages, and development of restoration plans, where appropriate (NCP Sections 300.430{b}{7} & 300.615). The lead agency also has the responsibility to coordinate planning and investigation of these releases with the natural resource trustees.

Section 300.160 of the NCP specifies that the "lead agency shall make available to the trustees of affected natural resources information and documentation that can assist the trustees in the determination of actual or potential natural resource injuries". This means that an installation's RPM should notify the affected trustees when there is a release to the environment that could injure a natural resource. Natural resources include land, fish, wildlife, biota, surface water, groundwater and drinking water supplies. RPMs should assure that any ERA performed at their installation is coordinated with the trustees.

Trustees are Federal, State and Tribal governments who have land management responsibilities, jurisdiction, or ownership over natural resources. At the Federal level, five cabinet Secretaries (Agriculture, Commerce, Defense, Energy, and Interior) have been designated as trustees by the President. The Secretary of Defense has delegated trustee responsibilities to the respective military service Secretariats. In a circumstance where DoD is responsible for the release of a hazardous substance, the specific Service may assume three separate and concurrent roles: (1) potentially responsible party; (2) lead response agency; and (3) natural resource trustee. Each state Governor has designated one or more state agencies to serve as trustee for resources under state management or control. Tribal Chairs, or their designees, serve as trustees for Tribal interests. The U.S. Environmental Protection Agency is not a trustee agency. The trustees most likely to be involved with a DoD restoration project, besides DoD, are the U.S. Fish & Wildlife Service (USFWS), the National Oceanic and Atmospheric Administration (NOAA) and the State in which the release occurred.

1.6 Technical Support For Ecological Risk Assessment

Each of the three Services has a process for technical support, review, and approval of the ERA. It is beyond the scope of this document to describe these processes in detail. RPMs should review the following regulations and instructions that are applicable to their respective

Service: U.S. Army Regulation, Environmental Protection and Enhancement, AR 200-1, Sections 1-18 and 11-9; U.S. Air Force Instructions (AFI) 32-7020, Section 1.4 and AFI 48-119, Section 8.0; and U.S. Navy Chief of Naval Operations Policy for Conducting Ecological Risk Assessments (Ser N453E/9U595355 dated 5 Apr 99). The RPM must follow ERA review and approval requirements specific to their Service.

Technical support for ERA is available within each Service. The RPM should first consult with technical experts assigned to each ERA site. If further assistance is needed to resolve site-specific technical problems, members of the Tri-Service Ecological Risk Assessment Work Group (TSERAWG) are available. The purpose of the TSERAWG is to exchange programmatic, regulatory, and technical information, and to develop and coordinate joint Service activities to aid RPMs in conducting ERAs. To enlist the service of the TSERAWG, contact your representative Service POC (Appendix C). The POC will direct the RPM to a TSERAWG member, or another person with expertise related to the problem. Appendix C also lists Internet sites of organizations within the Department of Defense that offer technical assistance and information for ERA. Each POC can direct the RPM to personnel and resources that can help decide:

- If an ERA should be conducted.
- The level of effort required at a particular site.
- What portions of the ecosystem need to be sampled and analyzed.
- How to determine the magnitude of risk.

Consulting with TSERAWG experts can help the ERA proceed more efficiently and ensure that the ERA meets regulatory requirements. Also, it may help to establish a relationship with your regional U.S. EPA Biological and Technical Assistance Group (U.S. EPA BTAG) (Appendix E). Their concerns can then be discussed with the decision-makers at the site when planning the ERA.

2. ECOLOGICAL RISK ASSESSMENT – THE BASICS

This section describes the different phases of the ERA and introduces many of the terms and components necessary to manage an ERA. For a more detailed description, please refer to Section 4.

2.1 ERA: A General Overview

An ERA is generally performed during the RI phase of a CERCLA/SARA project or during the RFI phase of a RCRA project, although it may be initiated earlier. Most ERAs are divided into a screening level (Tier 1) ERA and a baseline (Tier 2) ERA (Figure 1). A screening level ERA is a simplified risk assessment that can be conducted with limited data and uses conservative assumptions to minimize the chances of concluding that there is no risk when in fact a risk exists. In a baseline ERA, the conservative assumptions are eliminated and replaced with best estimates to more accurately assess the site's risk. When an ERA is conducted earlier than the RI or RFI phase, it is a screening level ERA.

Regardless of whether a screening or baseline ERA is being conducted, the following process is always followed: Planning, Problem Formulation, Analysis, Risk Characterization, and Risk Management (Figure 2). During both Planning and Risk Management, it is vital to have discussions between both the risk assessor (the person responsible for conducting the ERA) and the risk manager (the person responsible for the installation's restoration project as a whole; generally this is the RPM or his/her supervisor) because they both bring important perspectives to the table. During Problem Formulation, Analysis and Risk Characterization, the risk manager (RPM) will be less involved in day to day decisions, but still should remain aware of what is going on.

2.1.1 Planning

Planning involves the determination of the level of effort necessary for the ERA. This is accomplished during discussions among the RPM, risk assessor, risk manager, stakeholders, regulators, and others involved in the decision process. Every attempt should be made in coming to an agreement on the following issues before proceeding into the risk assessment.

- Establish management goals (i.e., the plant, animal, or ecosystem we are trying to protect).
- Agree on the scope, complexity, and focus of the ERA. Include expected output/results and what technical and financial support will be needed.
- Agree upon methods to be used during the ERA. These methods must be scientifically defensible and should determine if management goals are met.
- Establish times in the ERA where major decisions will be made and how these decisions will be made. Key decisions should be documented in writing for future reference.

Figure 1. Components of Screening and Baseline Ecological Risk Assessment Process

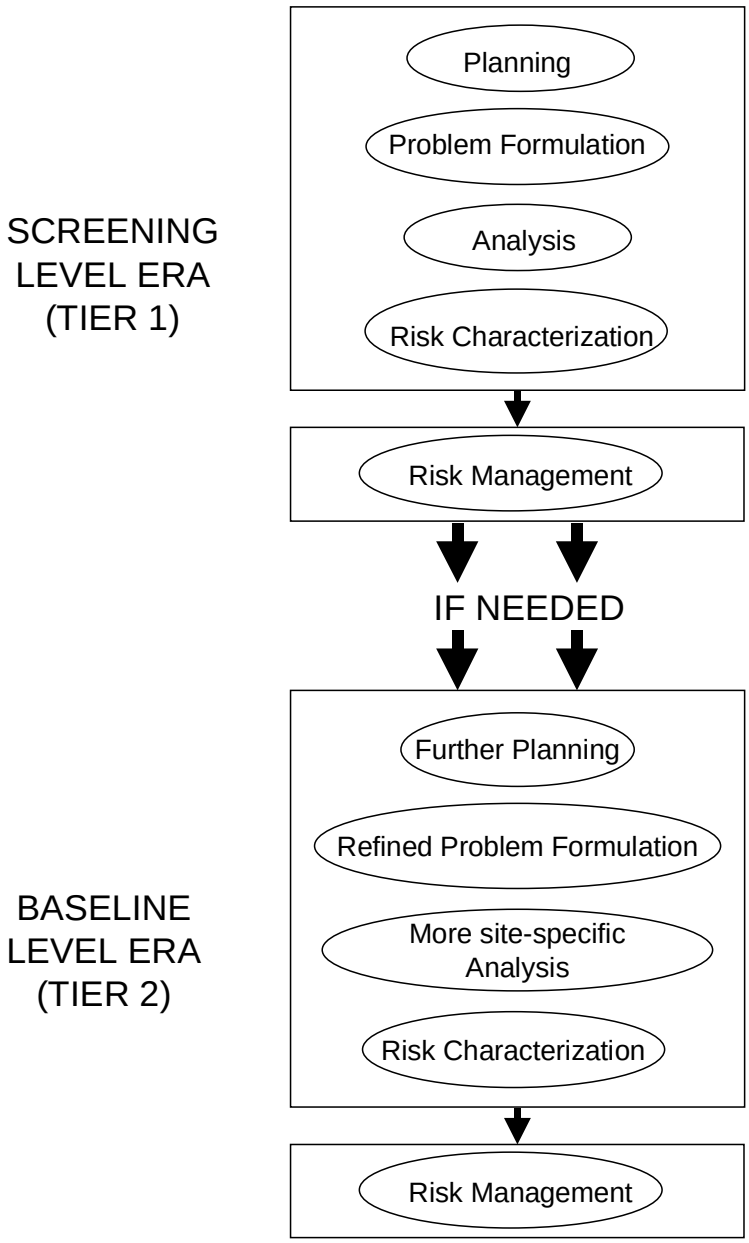
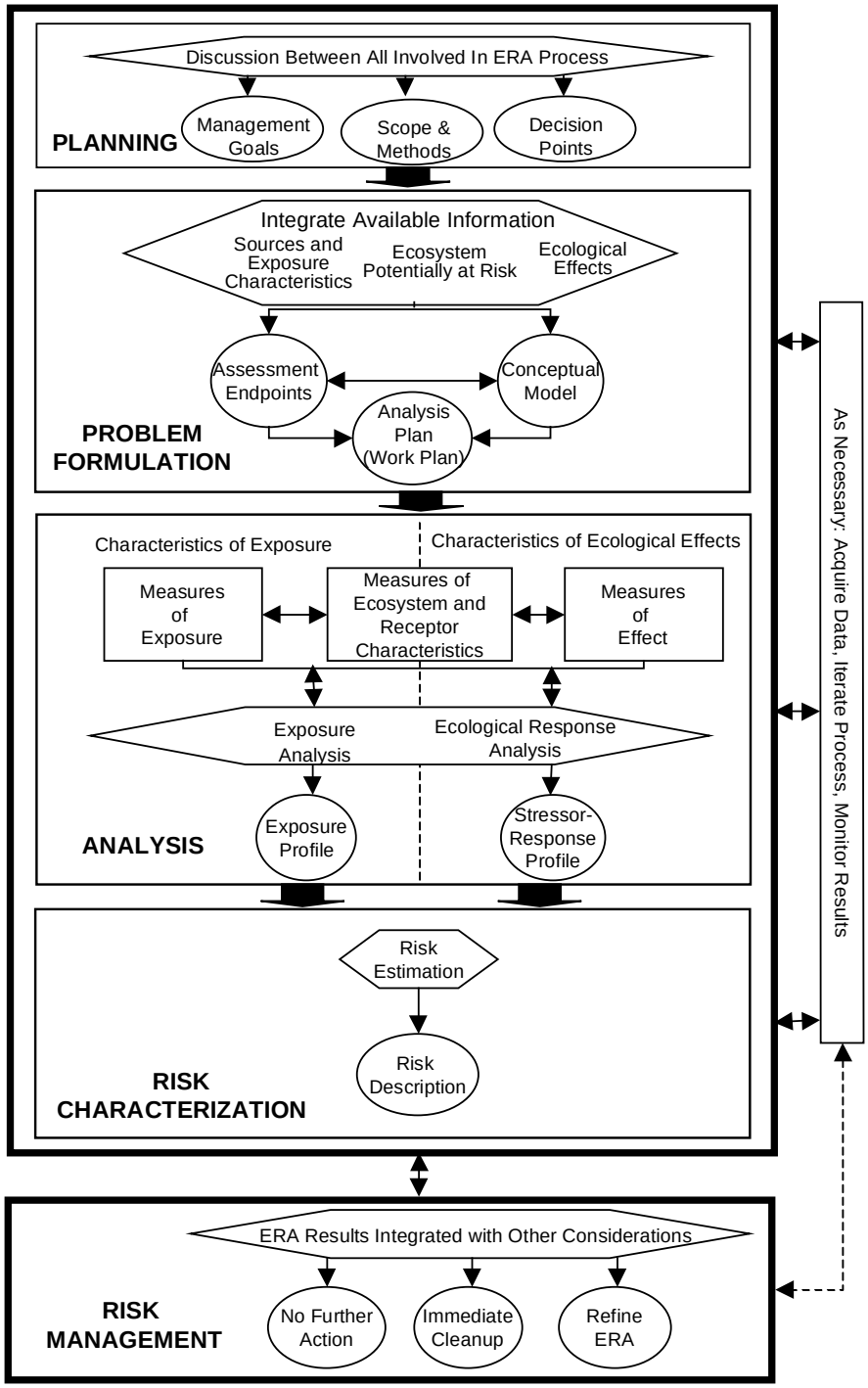


Figure 2. The Ecological Risk Assessment Framework. Within each phase, rectangular boxes designate inputs, hexagon-shaped boxes indicate actions, and circular boxes represent outputs [adapted from 3].



2.1.2 Problem Formulation

The overall strategy for estimating risk at your site is developed in Problem Formulation. In order to succeed, the ERA Problem Formulation must be well developed. This component of the ERA should further clarify the objectives of the ERA, create a conceptual site model, define the receptors potentially at risk, and present a plan to analyze data and characterize risk.

The sequence presented below shows generally how the ERA proceeds. In reality, many of these events occur simultaneously and are changed and revised until all available information is collected. For example, the risk assessor usually creates a conceptual model early in Problem Formulation while stressor and exposure characterization are occurring. The conceptual model and the endpoints (see below) are then finalized at the end of Problem Formulation, after all existing information has been collected and evaluated for validity and relevance to site conditions.

- Stressor and Exposure Characterization - Collect information about properties of the contaminants of potential ecological concern (COPEC), as well as any other stressors at the site and determine if ecological components (e.g., plants, mammals, fish) are, or may be, exposed to the stressors.

- Ecological Components Potentially at Risk - Select what ecological components are, or may be, exposed to the COPEC.

- Ecological Effects - From existing literature, identify potential ecological effects, based on the properties and toxicity of the COPECs.

- Conceptual Site Model - Create a model that shows potential exposure and pathways of the contaminants through the environment to ecological components. The model explains how a COPEC (stressor) might affect ecological components.

- Data Gaps - Determine if enough data and other site information are available to adequately characterize risk. If data gaps exist, identify what data or information is needed and why.

- Assessment Endpoints - Determine what specific ecological components are to be protected, and what attributes of these components must be protected. Choose Assessment Endpoints that describe the environmental effects that will drive the decision making process (e.g., reduction of a key species or destruction of a community ecosystem).

- Measurement Endpoints - Identify indicators that determine if effects to the Assessment Endpoints are occurring or may occur. These indicators may be measures of exposure or measures of effect, and must be specifically related to the Assessment Endpoints.

- Work Plan - The work plan documents the decisions and evaluations made during problem formulation and identifies additional investigative tasks needed to complete

the evaluation of risks to ecological components. The work plan for a screening level ERA describes the process for completing the screen. The work plan for the baseline ERA includes both the baseline process and field data collection parameters.

2.1.3 Analysis Phase

The Analysis Phase of the ERA consists of data collection, the technical evaluation of data, the calculation of existing and potential exposures, and ecological effects at the site. The analysis is based on the information collected, and often includes additional assumptions or models to interpret the data in the context of the conceptual site model. For the exposure and ecological effects characterizations, the uncertainties associated with the field measurements and with assumptions where site-specific data are not available, must be documented.

2.1.4 Risk Characterization

In Risk Characterization, the likelihood and severity of the risk is related back to the Assessment Endpoints and the ERA's uncertainty is described. The discussion of risk should be thorough enough to assist the risk manager in determining any necessary actions for the site. Risk characterization is composed of two parts, risk estimation and risk description.

Risk estimation is the process of determining the probability or likelihood of adverse effects on Assessment Endpoints. This is calculated by integrating the exposure information with the exposure-effects information and summarizing the associated uncertainties. For example, in a screening level ERA, Hazard Quotients are most commonly used to show relative risk.

Risk description provides data important for interpreting the risk results and should specify the level of adverse effects to the Assessment Endpoints. Risk results need to be summarized. Confidence in the estimate is generally assessed through a discussion of the various pieces of information and data gathered during the ERA process. The ecological significance and magnitude of the risks to the Assessment Endpoints must be included.

2.1.5 Risk Management

In risk management, the results of the ERA are integrated with other considerations to make and justify remedial decisions. In a screening level ERA, the risk management decision is whether or not a baseline ERA is necessary for the site. At the end of a baseline ERA, the risk manager (RPM) must balance risk reductions from site cleanup with the impacts caused by the cleanups themselves. Inputs from risk assessors, the regulatory community, and other stakeholders must also be considered.

2.2 U.S. EPA's 8-Step ERA Process

In 1997, USEPA published *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments* (ERAGS) [4] (Figure 3). The ERAGS document describes an eight-step process within a tiered approach for performing ERAs that incorporates the five components of the ERA addressed in section 2.1 above. The EPA eight steps are as follows:

Step 1. Screening-Level Problem Formulation and Ecological Effects Evaluation

Step 2. Screening-Level Preliminary Exposure Estimate and Risk Calculation

Step 3. Baseline Risk Assessment Problem Formulation

Step 4. Study Design and Data Quality Objectives

Step 5. Field Verification of Sampling Design

Step 6. Site Investigation and Analysis of Exposure and Effects

Step 7. Risk Characterization

Step 8. Risk Management

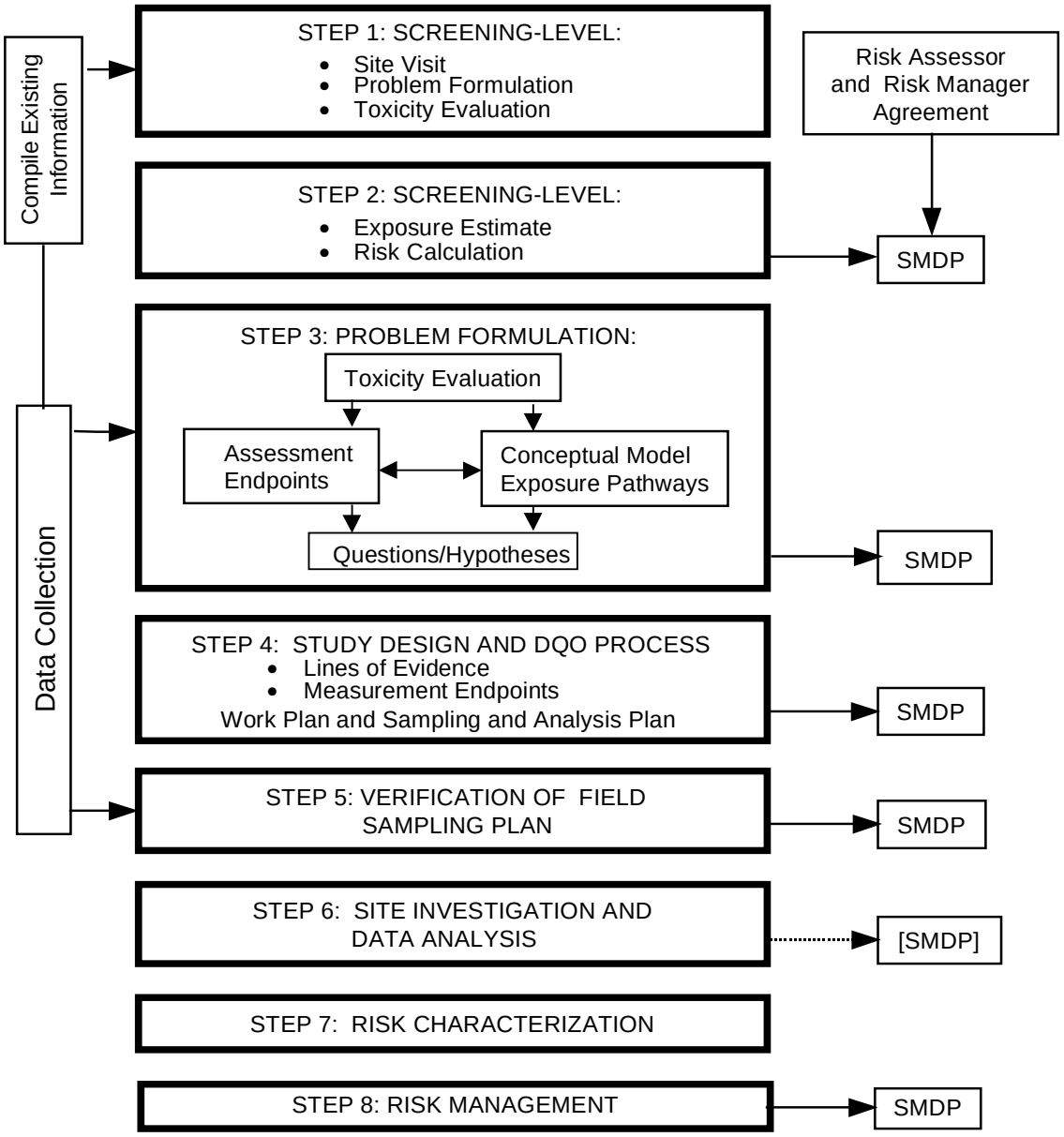
Within these eight steps, ERAGS provides additional structure by including five decision points that require meetings between the risk assessors and the risk managers. The risk managers evaluate and then approve or redirect the work up to that point. EPA calls these meetings scientific/management decision points (SMDPs). EPA notes that the SMDPs are significant communication points that should be passed only with the entire group's consensus. SMDPs occur at the end of steps 2, 3, 4, 5 and 8. An optional SMDP may be needed after step 6. The outcome or recommendation resulting from each SMDP is as follows:

Rule of Thumb #4

Effectively utilize SMDPs (scientific/management decision points) in the risk management process.

- Step 2 SMDP - Decision about whether a baseline ERA is needed or not.
- Step 3 SMDP - Agreement by all parties involved on the conceptual model, including Assessment Endpoints and exposure pathways.
- Step 4 SMDP - Agreement by all parties on the Measurement Endpoints, study design and analysis, and data interpretation.
- Step 5 SMDP - Written approval of the ERA Work Plan.

Figure 3. Eight-step Ecological Risk Assessment Process for Superfund



- Step 6 SMDP (optional) – Agreement by all parties to add new Measurement Endpoints and to revise the ERA Work Plan. This SMDP is needed only if alterations to the ERA Work Plan become necessary. †

- Step 8 SMDP - Signature of the Record of Decision.

Although EPA's process has eight steps, because of the way they are grouped, an ERA performed in accordance with the ERAGS document is really a tiered process. Steps 1 and 2 are grouped together and are referred to as the screening level ERA. Steps 3 through 7 are grouped together and are referred to as the baseline ERA. Step 8 is actually not part of the risk assessment. Rather, step 8 fits in towards the end of the Feasibility Study when the detailed evaluation of alternatives is performed and a cleanup decision is made. Under the EPA guidance, both the screening level ERA and the baseline ERA incorporates the five basic components of the risk assessment process described in section 2.1.

† Any new Measurement Endpoints must be evaluated according to their utility for inferring changes in the Assessment Endpoints and their compatibility with the site conceptual model. Proposed changes to the ERA Work Plan must be made in consultation with the risk manager and risk assessors. The risk manager must understand what changes have been made and why, and whether risk management decisions can be made from the new information.

3. TRI-SERVICE APPROACH TO ECOLOGICAL RISK ASSESSMENT

The May, 1996 *Tri-Service Procedural Guidelines for Ecological Risk Assessments* [1] outlined an approach to keep the ERA focused on accurately determining risk by using a tiered approach and each of the Services employs such an approach. Although differences exist among the Service-specific approaches, all follow similar principles regarding the design and conduct of ecological risk assessments. In addition, all are consistent with the U.S. EPA's 8-Step ERA process.

3.1 Screening Level ERA (Tier 1)

Each of the Services employs a tiered approach that includes a screening level ERA and a baseline ERA. Among all three Services, the screening level approach is conducted under Tier 1. A Tier 1 ERA is generally a highly conservative, desktop study, where little or no field data (other than visual observations) are collected or analyzed. The following items should be included:

- A literature study of what is known of the site stressors and ecological components, including historical site information and existing laboratory and field data.
- Fate and effects models should be performed on existing data to estimate risk. Tier 1 modeling is highly conservative to ensure protection.
- Site visits must be conducted to survey ecological components and to confirm complete exposure pathways.
- Results of a Tier 1 ERA are then used to decide whether:

  - There is adequate information to conclude that no significant ecological risks exist. The assessment should stop.

  <u>or</u>

  - There is adequate information to conclude that the risk is so great that action (i.e., remediation, containment, etc.) is warranted immediately.

  <u>or</u>

  - There is not adequate information to estimate risk (i.e., data gaps) or the risk estimate is believed to be too conservative or uncertain to recommend remediation. The assessment should proceed to the baseline ERA (Tier 2).

All parties responsible for assessment, management and regulation of the site should have input and agree upon this decision.

3.2 Baseline ERA (Tier 2).

Each of the Services conducts baseline ERAs as part of Tier 2. A Tier 2 ERA uses more site-specific information than Tier 1. Proceeding to Tier 2 is recommended when there is a need to reduce uncertainty. Performing laboratory or field studies to clarify exposure or effects may refine data inputs. As more site data are incorporated, the risk estimations become less conservative. The following items are included in a baseline ERA:

- Incorporate new data into fate and effects models. The baseline ERA emphasizes best estimates, replacing overly conservative estimates with site-specific data.
- Studies that address site-specific issues.
- Short term laboratory tests (usually less than 6 months including design, preliminary testing, definitive testing, and statistical analysis) or limited field studies (e.g., collecting more water or soil, or collecting a better sample of a particular animal population) to fill data gaps in exposure analysis or ecological effects.

Results of a Baseline ERA are then used to decide whether:

- There is adequate information to conclude that no significant ecological risks exist. The assessment should stop.

or

- There is adequate information to conclude that the risk is so great that action (i.e., remediation, containment, etc.) is warranted immediately.

or

- There is not adequate information to estimate risk (i.e., data gaps) or the risk estimate is believed to be too conservative to recommend remediation. The assessment should be refined.

All parties responsible for assessment, management and regulation of the site should have input and agree upon this decision.

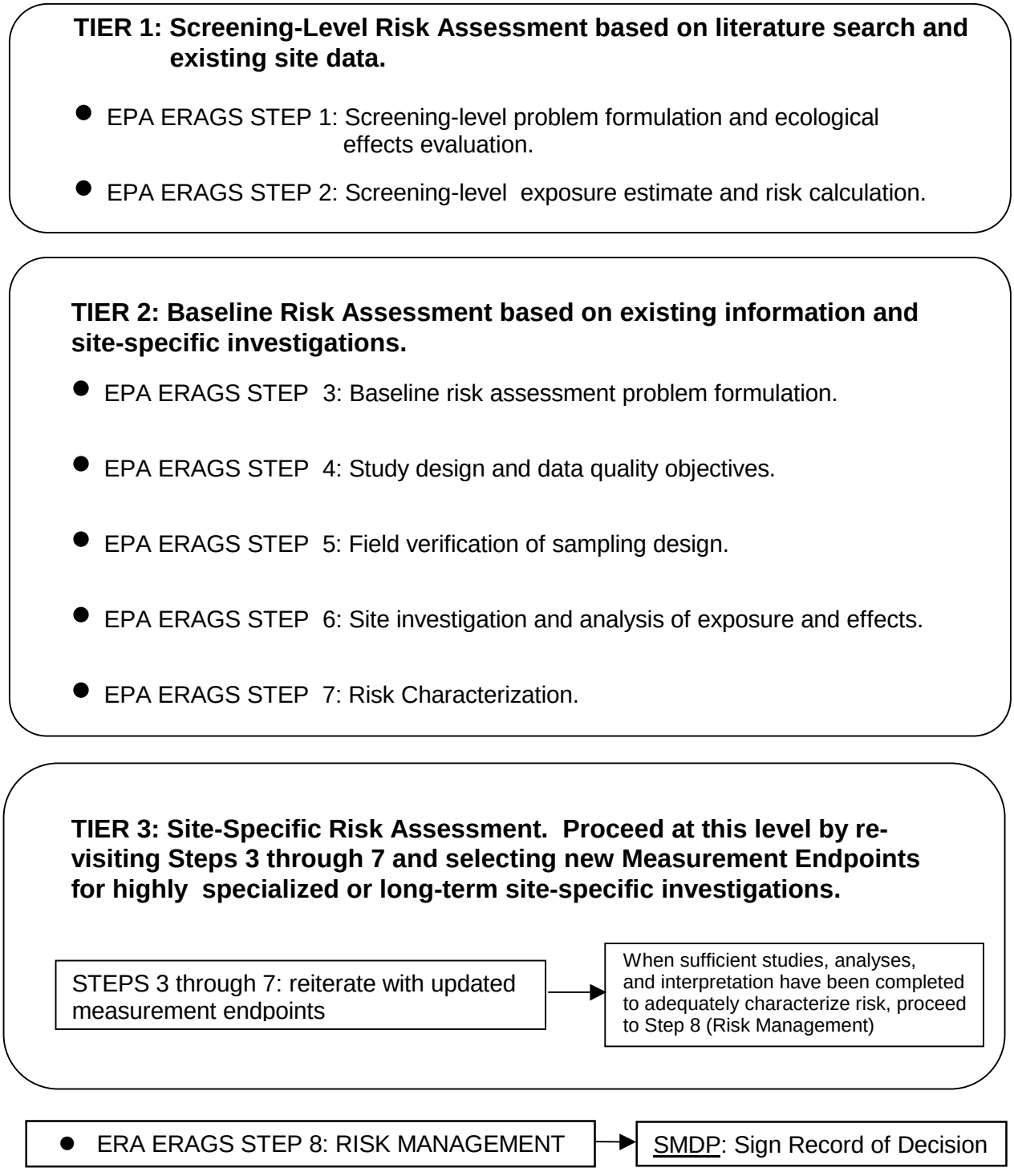
3.3 Army and Air Force ~~A~~approach

In the Army and Air Force approaches, the Tier 2 Baseline ERA is used to conduct site-specific ERAs as described above. The Army and Air Force have defined a Tier 3 effort for larger sites with complex ecosystems where there is a need to collect further data to reduce uncertainty (Figure 4). The Tier 3 effort is an iteration of the baseline ERA (steps 3-7) in accordance with ERAGS [4]. This Tier 3 ERA involves longer-term studies and more extensive tests to resolve issues or risks identified in the Tier 2 study and may include:

- More complex and/or longer term studies (> 6 months) to fill data gaps.
- Studies that include population- and ecosystem-level field tests that require more time and effort than simple surveys. These studies usually determine effects such as ability of wildlife to reproduce, or changes in plant community structure.

Results of Tier 3 are used to decide if, and to what extent cleanup is warranted, or to continue monitoring specific onsite ecological components.

Figure 4. Army and Air Force ERA Process



3.4 Navy Approach

In the Navy tiered approach, the baseline ERA is conducted entirely within Tier 2, whereas Navy Tier 3 focuses on the ecological evaluations of remedial alternatives (Figure 5). The Tier 2 Baseline ERA is the most extensive activity within the Navy ERA process, both in terms of data collection and analysis, cost, and effort. Tier 2 has two sets of objectives, one dealing with risk management and decision-making, and the other with focusing efforts and identifying assessment objectives. From a risk management perspective, the primary objectives of Tier 2 are to:

1. Identify which, if any, of the contaminants retained as COPECs by the Tier 1 evaluation truly pose an unacceptable risk; and

2. Develop cleanup goals for those COPECs identified to pose unacceptable risks.

The Navy Tier 2 baseline ERA is more site-specific and technically rigorous, and much less conservative than the Tier 1 screening assessment. It follows steps three through seven of the EPA ERAGS process to evaluate ecological risks and to determine whether site remediation is warranted from an ecological perspective. These steps are:

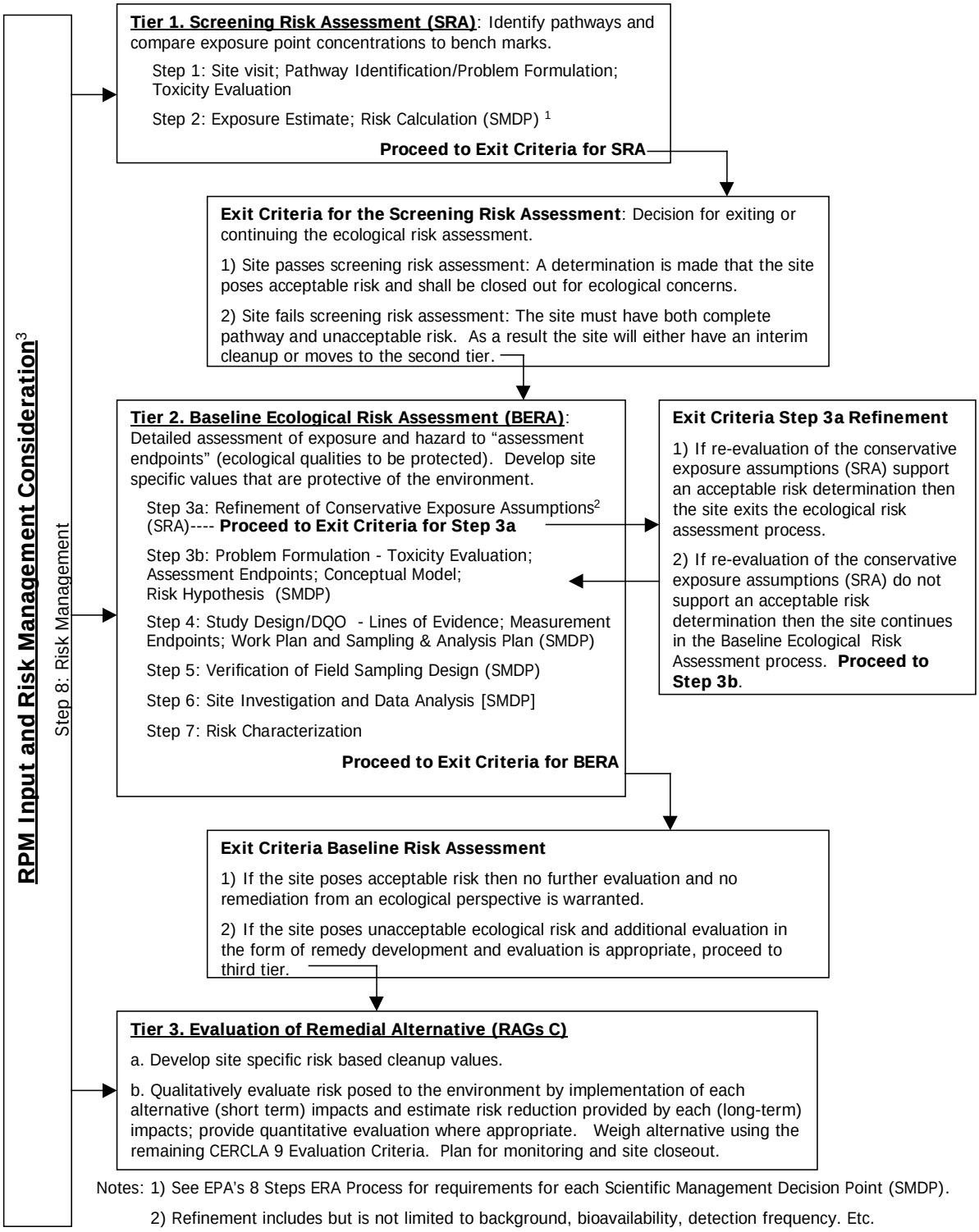
- Problem Formulation (including a Tier 1 re-evaluation, Navy step 3a)
- Study design and DQO Development
- Verification of Field Sampling Design
- Site Investigation and Data Analysis
- Risk Characterization

The Navy Tier 3 is the evaluation of remedial alternatives with regards to:

- the effectiveness of reducing ecological risks to acceptable levels;
- ecological impacts associated with remedy implementation; and
- residual risks.

The primary objective of Tier 3 is to assist the RPM in identifying a site-specific remedy that will reduce both ecological and human health risks to acceptable levels. The ecological evaluations conducted under this tier focus on the nine Remedy Evaluation Criteria identified in the National Contingency Plan (NCP).

Figure 5 Navy Ecological Risk Assessment Tiered Approach



Notes: 1) See EPA's 8 Steps ERA Process for requirements for each Scientific Management Decision Point (SMDP).

2) Refinement includes but is not limited to background, bioavailability, detection frequency. Etc.

3) Risk Management is incorporated throughout the tiered approach.

4 ECOLOGICAL RISK ASSESSMENT – THE DETAILS

This section describes the phases of the ERA in greater detail, emphasizing what the RPM should expect from the risk assessor throughout the ERA process.

4.1 Planning

Once it is decided to move forward with the ERA, the RPM must decide what is necessary for completion of the assessment. This is accomplished through discussions among the RPM, risk assessor, risk manager, stakeholders, regulators and others involved in the decision process. Management Goals (i.e., what we are trying to protect) should be clearly defined. Goals should be achievable within the constraints of available resources and the uncertainties of the analyses. The following list will help make planning decisions.

- What management decision will the risk assessment support (i.e., is cleanup necessary for a contaminated site)?
- What are the time and budgetary constraints for performing an ERA?
- What types and how many studies will be performed?
- What level of acceptable uncertainty allows a risk management decision to be made?
- What are the reference conditions (Section 4.3.4) against which possible adverse effects will be compared?

Good planning is critical to the success of the ERA. An initial site visit should be conducted to establish a working knowledge of the site to assist in Problem Formulation. A checklist for the site visit is given in Appendix B of *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments* [4]. Strengths and weaknesses of ERA case studies originate, in large part, from decisions made during the preliminary planning stage.

4.2 Problem Formulation

4.2.1 Stressor Characteristics

Known chemical and physical properties of contaminants at the site must be identified and characterized. The risk assessor must also describe potential chemical, physical, and biological stressors that may interact with the contaminants, or mimic symptoms of the contamination. These stressors may occur naturally, such as fish parasites or naturally high levels of metals in the soil, or be the result of human activities such as soil compaction by tracked vehicles. The distribution in space and time, and potential interaction of these stressors should be described. Information collected about stressor characteristics in Tier 1 should include:

- The environmental fate and toxicity of chemical stressors (contaminants). Such information may be obtained from databases (Appendix D). Site records, installation assessments, and reports on chemical storage, use, and distribution

may also yield valuable data. Additional information may be obtained from the Defense Technical Information Center (DTIC; telephone 800-225-3842, web site http://www.DTIC.mil).

- The relationship between the chemical and physical properties of the contaminants and the biological, chemical, and physical characteristics of the ecosystem.

If the ERA proceeds to Tier 2, conduct a more in-depth literature search on the environmental fate and toxicity of any contaminants not eliminated during Tier I screening (i.e., COPECs), and/or collect and analyze site-specific field data.

4.2.2 Identifying the Ecosystem Components Potentially at Risk

Use information collected from analysis of Stressor Characteristics to help select ecological components that have the potential to be affected by the stressor. Characterize ecosystem properties by determining:

- Ecosystem Structure (i.e., types and abundance of different species and their relationships, including threatened and endangered (T&E) species).
- Ecosystem Function (i.e., ecosystem energy source, pathways of energy utilization, and nutrient processing).
- Properties of the environment that affect bioavailability (i.e., can the COPEC be taken up by plants or animals?)
- Properties of abiotic (non-living) components such as surface water or soils (e.g., dissolved organic matter, hardness, pH, soil texture, organic matter content).
- The nature and history of past disturbances.
- Ecological components that have been negatively affected (e.g., fish kills).

At this point, it is important to emphasize that not all aspects of ecosystem structure and function need to be analyzed in every risk assessment. The extent to which ecosystem properties are analyzed depends upon the nature of the stressors and ecosystem components, bioavailability, and the resources available. Analyses should concentrate on those ecosystem components that are potentially at greatest risk based on the properties of the contaminants and the potential impacts of the contaminants on ecosystem components. T&E species, if present, should be considered. This does not mean that extensive studies need to be done. Much of this information often can be gathered from previous studies, simple field surveys, or models.

4.2.3 Ecological Effects

Ecological effects in Tier 1 of the Problem Formulation phase should be derived from published toxicity studies (journal articles or technical reports) related to the contaminants and ecological components of concern. Published data may come from field observations (e.g., fish kills, changes in aquatic community structure), laboratory tests (e.g., single species toxicity tests or microcosm studies), or results of modeling studies. These data, together with the distribution patterns of the COPEC within the site, can help characterize the extent of ecological effects. Analysis of this information can help focus the assessment on specific stressors and on ecological components relevant to the site.

If it is decided that a Tier 2 ERA is needed, ecological effects data should be derived from literature about new COPECs (if any) discovered in Tier 1. New data published about all of the COPECs should also be included.

4.2.4 The Conceptual Model

The conceptual model is a discussion of possible exposure pathways. The conceptual model includes a simplified schematic of possible exposure pathways, such as food webs, that show how contaminants are transported from their sources to the ecological receptors. The usefulness of a conceptual model diagram is dependent on detailed written descriptions and justifications for the pathways shown. Without this, diagrams can misrepresent the process. Development of a conceptual model is very important to the preparation of a credible sampling design (see Work Plan, section 4.2.7) to support the risk assessment.

Constructing exposure scenarios can help to describe exposure and effects relationships illustrated in the Conceptual Model. An example is shown below.

Conceptual Model Scenario Example:

- Source - explosives burning ground.
- Environmental transport – rate of movement of explosives through soil column.
- Partitioning of the Chemical in Environmental Media – distribution of contaminants between inorganic and organic soil fractions.
- Chemical/Biological Transformation – photolysis, biodegradation.
- Potential Routes of Exposure – ingestion by wildlife, plant root absorption.

The risk assessor should evaluate only those complete (or potentially complete) exposure scenarios that are most likely to cause an adverse effect. Scenarios should relate to the stressors, potential biological receptors, and environmental conditions at the site. These pathways are then evaluated in the Analysis phase. It is important that any assumptions not evaluated in the Analysis phase be addressed in the uncertainty section of the Risk Characterization phase.

4.2.5 Identify Data Gaps

After data about the contaminants, ecological components, and site characteristics have been collected, and the Conceptual Model has been established, it is important to identify data gaps. Data gaps exist if there is too little information to determine if: 1) complete exposure pathways exist or, 2) contaminant concentrations found on site can or cannot cause toxic effects. When data are insufficient to resolve issues and draw a conclusion within the acceptable level of uncertainty, the ERA must continue. Hopefully, by the end of the screening level ERA (Tier 1), enough information exists to eliminate some or most of the COPECs, so that the baseline ERA can focus only on those COPECs that are the risk drivers.

4.2.6 Endpoint Selection

An endpoint is defined as a characteristic of an ecological component (e.g., mortality rate in fish) that may be affected by exposure to the stressor. Two types of endpoints, Assessment and Measurement, are used in the ERA to determine risk to the ecosystem.

Assessment and Measurement Endpoints are selected after the biological, regulatory, and management goals have been established. The risk assessor should then use information collected from a review of stressor characteristics, the ecosystem potentially at risk, and the potential ecological effects to select endpoints. It is important that all involved parties collaborate to agree on endpoints before proceeding to the Analysis phase. RPMs should contact their technical support personnel for assistance.

An Assessment Endpoint is defined as: An explicit expression of the environmental value to be protected [2]. Specifically, an Assessment Endpoint includes both an ecological component and important attributes of that component. Three principal criteria for choosing Assessment Endpoints [3] are:

- Ecological relevance. These endpoints reflect important characteristics of the ecosystem and help maintain the natural structure, function, and biodiversity of the system.
- Susceptibility to the known or potential stressors. Ecological components are considered susceptible when a human-induced stressor to which they are exposed affects them.
- Whether they represent management goals. These endpoints are based on values and organisms that people care about but meet criteria for ecological relevance and susceptibility. Examples of these endpoints are commercial or recreational species, and ecosystems necessary for flood control.

Of these three criteria, ecological relevance and susceptibility are essential to select Assessment Endpoints that are scientifically valid.

Rule of Thumb #5

Bring all involved parties together early in the ERA process, to think through and come to agreement upon the Assessment Endpoints.

Rule of Thumb #6

Once the Assessment Endpoints are determined, they should remain unchanged throughout the ERA unless all parties agree to a necessary change or addition.

Ideally, Assessment Endpoints should have biological, as well as societal value, so that scientific information can be linked to the risk management process (e.g., management goals). However, ecological relevance should not be sacrificed for public perception.

Assessment Endpoints are described in ERAGS [4]. For the screening level ERA, Assessment Endpoints are any adverse effects on ecological receptors, where receptors are plant and animal populations and communities, habitats, and sensitive environments [4].

Assessment Endpoints usually cannot be measured directly (e.g., no more than 10% reduction in game fish production). When the Assessment Endpoint cannot be measured directly, Measurement Endpoints are selected that are specifically related to the corresponding Assessment Endpoints (e.g., mortality rate of caged bass).

A Measurement Endpoint is defined as*:* A measurable ecological characteristic that is related to an Assessment Endpoint [2]. Measurement Endpoints can be the results of tests, assays, surveys, etc. that are used to judge whether the Assessment Endpoints are met. Ideal Measurement Endpoints are cost effective and easily measured.

Retaining the Assessment Endpoints established in the Problem Formulation phase throughout each tier of the ERA provides focus and stability, so that other lesser issues don't cloud the goals, bog down the process, or add unnecessary costs. If the ERA proceeds to the baseline level, the Assessment and Measurement Endpoints should change to become more site-specific.

Relating Measurement Endpoints to Assessment Endpoints is important to produce risk estimates that are scientifically sound and that address management goals. In Tier 1 (screening ERA), Measurement Endpoints can be benchmark or threshold values such as U.S. EPA's Ambient Water Quality Criteria (AWQC). It is important that such screening values are relevant to the ecosystem at your site. For example, a concentration of a heavy metal has been detected in a stream that exceeds the AWQC. The risk assessor suggests that this metal should be a COPEC. The RPM should then ask: Does a complete exposure pathway exist?; Are the organisms used to establish the AWQC present at the site? Examples of Assessment Endpoints and corresponding Measurement Endpoints are presented in Table 1.

Rule of Thumb #7

For each Measurement Endpoint, RPMs should ask the risk assessor:

- What Assessment Endpoint does this Measurement Endpoint represent?
- What questions will be answered by the results of this test?
- What are the data criteria for judging whether the Assessment Endpoint has been met?

Rule of Thumb #8

If the ERA proceeds to the baseline level , the Measurement and Assessment Endpoints should change to become more site-specific.

The bottom line is, the Measurement Endpoint must represent the Assessment Endpoint. If it doesn't, then the test is of questionable value and should not be done. Asking the questions in Rule of Thumb #7 will help keep the ERA scientifically sound, efficient, and cost effective.

Table 1. Examples of Assessment Endpoints and Corresponding Measurement Endpoints for a Baseline ERA.

ASSESSMENT ENDPOINTS	MEASUREMENT ENDPOINTS	
	Measures of Exposure	**Measures of Effect**
[1]Coho salmon breeding success and fry survival.	Toxic chemical concentrations in water, sediments, and fish tissue.	Natural population structure (proportion of different size and age classes); Feeding, resting, and reproductive cycles; Laboratory evaluation of reproduction, growth, and mortality.
[2]Protection of piscivorous (fish eating) birds from eggshell thinning due to DDT exposure.	DDT concentration in surface water and sediment; Body burdens of DDT in forage fish (e.g., creek chub).	Eggshell thinning in belted kingfisher.

[1] Adapted from U.S. Environmental Protection Agency document, *Guidelines for Ecological Risk Assessment* [3].

[2] Adapted from the U.S. Environmental Protection Agency document, *Ecological Risk Assessment Guidance for Superfund* [4].

The examples shown in Table 1 are typical of those used in a baseline ERA. The type of Measurement Endpoint selected and the extent of analysis will depend on how much information is needed to evaluate the Assessment Endpoints. For instance, in both examples, measures of effect may not be needed if levels of contaminants in water and sediments are below toxic threshold levels. Experts familiar with bioaccumulation of contaminants in wildlife should be consulted to determine the appropriate action.

4.2.7 Work Plan

At the end of Problem Formulation, a detailed work plan should be written. The purpose of the work plan is to document decisions and evaluations made during Problem Formulation, and to describe, in detail, tasks to be performed in the Analysis Phase. These tasks should be those needed to accurately identify and characterize ecological risks.

The work plan should include the following:

- A general overview and background of the site including the site's physical setting, ecology, and previous uses.
- A summary of previous site investigations and uses.
- A site conceptual model.

- Assessment and Measurement Endpoints, and their corresponding data requirements.
- Procedures and methods.
- Statistical methods and design for sampling.
- Data Quality Objectives.
- A time schedule to estimate duration and completion dates of various phases of the assessment.

Work plans vary according to the specific needs of each ERA, but should be formulated and agreed upon by all parties involved prior to implementation. The work plan should contain an explanation of how the Measurement Endpoint data will correspond to the Assessment Endpoints. In formulating a work plan, the risk assessor must address how data gaps will be handled and clearly state the data quality objectives (DQOs) [2]. See *Guidance for the Data Quality Objectives Process* [7] for a detailed description.

Adhering to a good quality control program (or Good Laboratory Practices Guidelines) can reduce errors in measurements and sampling. Review of raw data, and verification of data entry values and procedures, minimize human errors. Field verification or model validation can reduce errors and uncertainty in simulation models. Independent review of the work plan can help reduce errors in study design. Consult with technical support personnel to obtain advice on good quality control practices.

4.2.8 Problem Formulation Summary

At the conclusion of Problem Formulation, it is important for all involved parties to determine the attributes and the focus of the rest of the assessment and to decide if the ERA should continue. RPMs should consult with their technical support personnel to help with the decision. Each of the following tasks should be accomplished by the end of Problem Formulation and documented in the work plan:

- Decide whether or not the risk assessment should proceed based on available information.
- Agree upon which exposure pathways to investigate.
- Select and agree upon Assessment Endpoints and their corresponding Measurement Endpoints.
- Select specific investigation methods.
- Select and agree upon data reduction and interpretation methods.

Rule of Thumb #9

Get regulator and stakeholder agreement on Assessment Endpoints, Conceptual Model, Measurement Endpoints, and Work Plan before proceeding with site investigation and risk characterization.

4.3 Analysis Phase

The Analysis Phase includes characteristics of exposure and characteristics of ecological effects (Figure 2). The magnitude of contaminant exposure and resulting ecological effects are determined. Products of the Analysis Phase are the exposure profile, derived from the Characterization of Exposure (Section 4.3.3), and the stressor-response profile, derived

from the Characterization of Ecological Effects (Section 4.3.6). These profiles are very important because they are used as the basis for risk characterization.

4.3.1 Analysis Phase Site Visit

Before implementing the work plan (Analysis Phase), the RPM, risk assessor, and technical support personnel should make at least one site visit. The site visit is a visual inspection of work sites proposed in the work plan. The site visit helps determine if the proposed methods will adequately fill data gaps. After the site visit, all involved parties should decide what, if any, methods should be changed or added. For example, due to the time elapsed between work plan preparation and implementation, the team should re-check the site to ensure that the proposed sampling still makes sense (e.g., ensure that a sufficient population of indicator species is present prior to collection activities, examine injured trees for insect damage prior to testing for chemical contamination).

4.3.2 Evaluate Data and Mathematical Models for Analysis

The risk assessor should critically evaluate data and models to ensure they can support the ERA. The risk assessor should:

- Determine the strengths and limitations of studies and models.
- Ensure that the objectives of the study or model coincide with the ERA objectives.
- Evaluate the quality of the study design and resulting data.
- Estimate the uncertainty. For example, how accurately does a laboratory test estimate what may happen in the field?

4.3.3 Characterization of Exposure

Exposure characterization describes the stressor's distribution in space and time and therefore determines which ecosystem components are potentially at risk and how they may be exposed to stressors. Collection and analysis of background or preliminary information on the COPECs, described in this section, is important to establish exposure pathways and potential cause-and-effect relationships.

Exposure Analysis

Exposure Analysis should:

- Describe the source of the stressor (chemical).
- Describe the distribution of the stressor or disturbed environment.
- Describe the contact or co-occurrence of the stressor with the ecological component.
- Result in an Exposure Profile (see below).

Exposure Analysis accomplishes the tasks shown above by examining Exposure Pathways. An Exposure Pathway is the course a chemical stressor takes from the source to an exposed organism.

Each Exposure Pathway includes:

- A source (or presence in the environment).
- An exposure point (where the stressor contacts the ecological component).
- An exposure route (a mechanism of uptake into an organism).

Rule of Thumb #10

If an Exposure Pathway is incomplete or does not exist, the pathway does not need to be evaluated further.

Presence of a chemical does not alone equate to exposure. Exposure is ultimately determined by whether organisms come in contact with the chemical and whether contact leads to uptake (bioavailability). Environmental fate and transport of the COPECs control both. A complete exposure pathway exists if: a bioavailable COPEC has the potential to move from a source through the environment and be taken up by an ecological component (e.g., an important plant or fish species). It is often difficult to recognize complete exposure pathways; contact your technical support personnel for guidance, if necessary**.**

Estimating contaminant bioaccumulation (the net accumulation of a chemical by an organism as a result of uptake from all routes of exposure) at the site through the food web is very important. If a contaminant bioaccumulates, then potential pathways exist to animals higher in the food web. If the bioaccumulation potential of the contaminant is low, then some pathways may be eliminated. The bioaccumulation potential of the COPECs is determined by analyzing the fate, transport, contact with organisms, and bioavailability as described above.

Environmental fate models in Tier 1 Exposure Analysis serve as a "screening analysis" to provide initial qualitative assessments of contaminant transport patterns in time and space. Most exposure models tend to be conservative because they are based on an assumption of equilibrium in dynamic systems, and thus overestimate exposure. Model validation is very important when using any predictive model. For example, if one is modeling bioconcentration of chemicals into fish at a particular site, the results of the model can be compared to actual measured concentrations of chemicals found in fish at that site.

Rule of Thumb #11

A model is only as good as the information that goes into it. Model outputs are estimates that must be validated. They are not infallible.

Exposure Profile

Once an Exposure Pathway is found to be complete, then an Exposure Profile is constructed by determining the concentration of the stressor and its distribution over the area of study. The exposure profile evaluates pathways and relates exposure or dose to Measurement Endpoints.

If exposure is not adequately characterized in the screening level ERA, evaluation of contaminant pathways should continue in the baseline ERA. All concerned parties should decide if a baseline ERA Exposure Characterization should be performed. Baseline level data collection can reduce the uncertainty of environmental fate and distribution estimates.

However, such sampling is expensive and time consuming. Be certain that further sampling is absolutely necessary to adequately characterize exposure.

4.3.4 Characterization of Ecological Effects

Characterization of ecological effects describes effects that are caused, either directly or indirectly, by the stressor, links these effects to the Assessment Endpoints, and evaluates changes in effects at varying levels of the stressor. This process is critical to the success of the ERA because data generated will be used to help estimate risk. Growth, mortality, and reproductive endpoints at the population level are generally the focus of the ecological effects characterization, unless T&E species are impacted. When T&E species are potentially impacted, the level of protection is for individual members of the population. Examples of ecological effects include:

- Behavioral effects.
- Lethal effects.
- Population changes.
- Community changes.
- Ecosystem structural or functional changes.
- Bioaccumulation and biomagnification of chemicals.
- Indirect effects such as loss of habitat or food source.

Reference Location

A Reference Location is an uncontaminated site used for comparison to contaminated sites in environmental monitoring (often incorrectly referred to as a control). Selecting appropriate reference locations is difficult but very important to accurately evaluate the ecological effects in an ERA. The reference location should be similar in media, habitat and geography, but not impacted by contamination from the site. Reference locations should be reflective of typical background and anthropogenic concentrations that are not attributable to the site of concern. For example, a reference site for a location with contaminated soil should have a similar soil type with similar vegetation and wildlife habitat. Undisturbed areas on the site (not subjected to contamination) may serve this purpose. However, off-site locations may be required, especially for aquatic habitats.

When choosing a reference location, the risk assessor should consult with people knowledgeable with characteristics of the area and seek information from organizations that have local records. Information may be obtained from organizations, such as those listed in Appendix F, and from Installation records.

Rule of Thumb #12

When choosing a reference location, make use of readily available scientific resources that have local site information**.**

Stressor/Response Profile

Data on "cause and effect" of the contaminant (stressor) at the site need to be formatted into a Stressor/Response Profile**.** Each Measurement Endpoint should, in theory, have its own profile. In practice, profile data may be hard to find or difficult to generate.

A stressor/response profile may include:

- No Observed Adverse Effects Concentration or Level (NOAEC or NOAEL).
- Lowest Observed Adverse Effects Concentration or Level (LOAEC or LOAEL).
- Lethal Concentration$_{50}$ (LC_{50}), Lethal Dose$_{50}$ (LD_{50}), Effective Concentration$_{50}$ (EC_{50}).
- The percentile of the population community or system affected versus exposure dose.
- Other quantitative measures.

One frequently used method for profiling exposure assessment and toxicity is the use of Toxicity Reference Values (TRV) [1]. The TRV method uses available toxicity data on a specific COPEC to generate an estimated No Observed Adverse Effects Level (NOAEL) for a species of concern at the site, with appropriate levels of uncertainty included in the process.

Rule of Thumb #13

Potential "cause and effect" relationships between contaminants and the ecological Measurement Endpoints must be established; otherwise further assessment is not justified. Both direct (e.g., fish kills) and indirect (e.g., loss of habitat) effects must be considered.

The TRV method is just one way to link toxicity to exposure. Other methods exist. TRVs should be just one of many criteria used to determine risk for a particular stressor at a particular site. Since calculation of TRVs frequently requires extrapolation of data, risk assessors often extrapolate between species, between responses, and from laboratory tests to the field, using highly conservative assumptions. Therefore, TRVs often overestimate the response of a particular organism to a particular chemical at a given site. Also, since extrapolations require professional judgment, the thought process used by the risk assessor to derive the TRV must be clearly and carefully documented. If the data (e.g., TRVs) used in the profile seem unreasonable, contact your technical support personnel for help.

Highly conservative assumptions are often used during Tier 1 (screening level) ERAs. If the ERA proceeds to the baseline level, more realistic assumptions must be made. If there is more than one iteration of the baseline ERA, the data and information gathered should reduce uncertainty and fill data gaps to enable the risk assessor to use best estimates.

4.3.5 Linking Exposure and Stressor-Response Profiles

During the final stages of the Analysis phase, ecological effects and exposure are integrated. Fate and effects data are objectively evaluated to determine if cause and effect exists for the stressor(s). Because all organisms undergo "normal" physical and biological stress(ors) in the field, any additional stress due to contaminants must be quantified. To this end, various statistical methods are used. Contact your technical support personnel if you need help to determine appropriate statistical methods for the studies performed at your site.

Rule of Thumb #14

The RPM should keep track of the agreed-upon Assessment and Measurement Endpoints, plans, decision criteria, and approvals. Experience has shown that when pre-conceived notions of risk are not supported by site-specific evidence, involved parties (e.g., risk assessors, regulators, and environmental trustees) may suggest unplanned and possibly unnecessary studies.

4.4 Risk Characterization

Risk Characterization integrates information on exposure-effects relationships and target populations (from direct sampling or from estimates derived from the literature). Results of Risk Characterization estimate the likelihood, severity, and characteristics of adverse effects caused by environmental stressors present at the site.

It is important to understand that Risk Characterization is determined by many factors, not by a single, directly measurable value. A weight-of-evidence evaluation (section 4.4.1) should be developed in advance of conducting risk estimation analyses. This procedure helps prevent biased conclusions by employing previously agreed-upon input information for deriving risk estimates. Risk calculations must always relate to Assessment Endpoints directly or through Measurement Endpoints. Risk calculations that are not related to Assessment Endpoints are not useful for risk management decisions. For ERA to be effective, Risk Characterization must be as accurate and scientifically sound as possible to meet the objectives of the assessment.

4.4.1 Weight-of-Evidence

The Weight-of-Evidence process relates multiple Measurement Endpoints to an Assessment Endpoint to evaluate whether significant ecological risk has occurred or is likely to occur. The Weight-of-Evidence Approach usually has three major components:

- Weight assigned to each Measurement Endpoint: The degree of weight usually depends on how well the Measurement Endpoint relates to the Assessment Endpoint and the quality of data (e.g., the degree to which Data Quality Objectives are met). It is important to get agreement up front from all stakeholders on the weight assignments prior to collecting the data.
- Magnitude of response in the Measurement Endpoint: Strong or obvious responses are typically assigned greater weight than marginal or vague responses.
- Concurrence among Measurement Endpoints: More weight is given to Measurement Endpoints that agree with each other.

The Weight-of-Evidence method helps interpret the data. This approach gives the RPM a good idea of the potential risks to all sensitive components of the ecosystem, along with a measure of the uncertainty involved with each risk estimation (see Section 4.4.2). Such information may be useful for making decisions about remediation and future use of a particular site. Refer to Menzie, et al. [8] for an in-depth explanation of the weight-of-evidence approach.

4.4.2 Risk Estimation

Two tools of risk estimation are the hazard quotient and probabilistic risk estimate. Each has its uses, and each supports certain decision points for a particular site. Additional tools are provided in U.S. EPA's *Guidelines for Ecological Risk Assessment* [3].

Hazard Quotient

The hazard quotient is a tool that is useful primarily in Tier 1 ERAs (although it may also be used in some baseline investigations). Simple hazard quotients are point estimates relating presumed exposure concentrations to known, or extrapolated, effects levels of toxicants. Conceptually, the hazard quotient is represented as:

$$HQ = EEC / TEC$$

Where: EEC is the measured or modeled concentration at the site, and TEC is the concentration corresponding to an acceptable level of risk. For example in Tier 1, the EEC may be the highest measured concentration at the site and the TEC may be the Ambient Water Quality Criterion. In a baseline ERA, the EEC should be a more realistic concentration (e.g., 95th percentile confidence limit value), and the TEC a more appropriate site-specific toxicity value. For models that use dose instead of site concentrations, the EEC is the dose corresponding to an acceptable level of risk and the TEC is a TRV. In either case, the units in the EEC and the TEC should cancel so that the HQ is unit-less.

Rule of Thumb #15

The ERA should use realistic, site-specific Hazard Quotients (HQs), rather than simply applying generic, overly conservative values and excessive safety factors. In general, simple point estimates of risk such as HQs are most valuable as indicators of the need for further evaluation, not for defining clean-up goals.

The hazard quotient method may be employed to estimate the possibility of an adverse effect from single sources. The ratio, or quotient, of the exposure value to the effect value provides the relative estimate of risk. Generally, ratios of EEC to TEC greater than 1.0 indicate a "potential risk." As a basis for risk assessment, separate hazard quotients are calculated for each contaminant/receptor pair. The quotient method yields only a single number, or point estimate. Therefore, probabilities of effects cannot be easily specified. Often, HQs are inappropriately added together to get a Hazard Index (HI) for multiple contaminants. ERAGS [4] states that it may be appropriate to sum HQs into an HI, but only for contaminants that produce adverse effects by the same toxic mechanism. For more guidance on the use of the HI, consult with your technical support personnel.

Probabilistic Risk Estimates

Probabilistic risk estimates are calculated by analysis of the “distributions” of exposure and effects, rather than using single values. Risk is quantified by the overlap between the two distributions, with greater overlap indicating greater risk. Therefore, contrary to the HQ method, the probability of risk can be estimated. The fundamental components of a Probabilistic Risk Estimate are:

- Identify contaminants of primary concern.
- Develop statistical distributions of concentration-dependent effects of contaminants on representative receptor organisms.
- Develop statistical distributions of site-specific exposure of receptor organisms to contaminants.
- Combine effects and exposure distributions to quantify probabilistic estimates of risk (overlap).

Probabilistic vs. Single Point Risk Estimates

Probabilistic estimates offer distribution of points rather than a single point. This allows the risk assessor to provide the RPM and risk manager with clearer statements of risk probability and therefore, less uncertainty than the HQ method. For example, if a risk management goal is "protecting 95% of species present in a body of water from adverse effects of cadmium," distributions of exposure and effects allow the risk assessor to determine realistic and protective concentrations if specific bioavailability factors are included. Thus, the risk manager can make more informed decisions regarding potential environmental impact associated with contaminant removal vs. exposure reduction (e.g., capping), natural attenuation, or no action.

In general, probabilistic estimates are most useful in the baseline ERA where the level of site complexity and the importance of decision-making warrant more accurate and precise risk evaluation. However, probabilistic approaches require more investment of resources and a cost-benefit analysis may be necessary to determine whether the probabilistic approach is cost-effective. Consult with your technical support personnel to determine the best risk estimation methods for your site.

Uncertainty Analysis

At best, Risk Estimation comes with uncertainty. This uncertainty may also be estimated (e.g., providing high or low degrees of confidence). The degree of uncertainty associated with the estimate of risk is related to the precision (goodness of fit) of the stressor-response profiles used. By the very nature of the lower effort and cost, Risk Characterization at lower tiers will have larger uncertainties. The greater cost of going to higher tiers has to be balanced against the benefit gained using more site-specific information to reduce risk uncertainty. Unfortunately, sources and effects of uncertainty can overlap throughout an ERA. Be sure that the risk assessor addresses and analyzes the uncertainty in all phases of the ERA.

Major sources of uncertainty include:

- Formulation of the conceptual model: Are the correct working hypotheses established?
- Incomplete information and data: Were fate and effects data collected for complete exposure pathways?
- Extrapolation: Do data from laboratory studies accurately represent site-specific species?
- Natural Variability: Did sampling design account for variance in spatial and temporal distributions of the chemical, biotic, and abiotic stressors?
- Procedural or Design Errors: Were data quality assurance plans used to minimize sampling errors and uncertainty?

4.4.3 Risk Description

Ecological Risk Summary

The ecological risk summary clearly reports results of the risk estimation and discusses the uncertainty of the assessment. This should include an overview of measured endpoints (or estimates) of exposure and ecological effects, bioaccumulation potential, integration of stressor-response profiles, or model predictions. This overview must also include a discussion of the uncertainty inherent in each phase of the assessment. Whenever possible, risk estimation results should be quantitatively expressed (e.g., there is a 30% probability of 25% mortality in American robins). For example, a different way of handling quantitative estimates comes from a study on the effects of molybdenum mine tailings on marine fish and invertebrates [9]. Scientists calculated the risk to aquatic organisms by developing a probability of exceeding a water quality criterion level for copper (over a 55-year period) and conservatively assuming 100% mortality if organisms were exposed to concentrations higher than the criterion. Hence, the probability of obtaining greater-than-criterion levels for copper in water or sediments becomes the probability of the effect.

The last step in risk description is determining the ecological adversity associated with the expected changes in the Assessment Endpoints. At this point in the ERA, the risks have been estimated and the supporting lines of evidence evaluated. The U.S. EPA defines ecological adversity as those effects that represent changes that are undesirable because they alter valued attributes of the environment under consideration. In this step, the risk assessor evaluates the amount of adversity. The following are the U.S. EPA's criteria for evaluating adverse changes in Assessment Endpoints [3]:

- Nature and intensity of effects.
- Spatial and temporal scale.
- Potential for recovery.

The extent to which these criteria are assessed depends on the scope of the ERA.

Summary decisions and projections of risk conclude the Risk Assessment process. At this point, the ERA should provide a good, scientifically sound estimate of risk and its ecological

significance, including an estimate of uncertainty for each contaminant of concern, and a description of remaining data gaps. The ERA should also clearly document potential environmental impacts from contamination at the site with respect to the Assessment Endpoints. A well-written ERA should include information necessary for the development of cleanup goals (i.e., in the Feasibility Study) if risk at the site is found to be unacceptable.

Monitoring and Assessment Validation

Monitoring may be useful in situations where: a) ecological risk cannot be determined over a short period of time, or b) significant residual contamination will be present after the remedial alternative is implemented. The decision to undertake monitoring is based on:

- Relative uncertainty of the risk assessment (more uncertain assessments, especially those based on single point estimates, may need a greater investment in follow-up monitoring).
- Projected exposure reductions associated with the remediation.
- Projected short- and long-term effects of the remedial action.

Properly designed monitoring programs serve simultaneously to assure the effectiveness of the cleanup and to validate the risk assessment and its application (i.e., determine the accuracy of the original estimate of risk). For example, if surrogate organisms are used as part of a baseline ERA evaluation of exposure (e.g., counting eggs in nest boxes), this monitoring process could be left intact, or repeated as necessary, following a remedial decision. Monitoring may be used in conjunction with a no-action decision to validate exposure levels predicted in the ERA. Conversely, if a cleanup action reduced bioavailability, monitoring would demonstrate that the exposure in the surrogate species declined. Prior to implementing monitoring programs, data quality objectives and an exit strategy must be developed.

5. RISK MANAGEMENT - WHERE DO WE GO FROM HERE?

Risk management is distinctly different from risk assessment. The ERA establishes whether a risk is present, and defines a range or magnitude of the risk. In risk management, the results of the ERA are integrated with other considerations to make and justify management decisions (e.g., tradeoffs between human and ecological concerns, implications of existing background levels of contamination, acceptable levels of uncertainty). Risk management decisions are made by the risk manager, not the risk assessor.

Clearly, there is a trade-off in risk management between active remediation (most currently available remediation technologies alter site habitat) and allowing contamination to remain onsite. Although it is desirable to make final management decisions that minimize risk, it is not always clear which is riskier, site remediation or allowing contamination to remain in-place. ERA uncertainty (described above) plays a crucial role in this decision, because the risk of habitat alteration associated with site cleanup must be balanced against the weight-of-evidence for contaminant-related risks.

Decisions about how to proceed at the end of each tier depend on whether the information gathered so far warrants remediation, another tier of the ERA, or no action. A thorough discussion of risk management is found in the *Risk Assessment Handbook, Volume II – Environmental Evaluation* [8]. Questions, adapted from *U.S. EPA Guidelines for Ecological Risk Assessment* [3], for the RPM to ask at the end of both a screening level and baseline ERA are:

- What effects from contaminants might occur?
- How adverse are the effects?
- How likely is it that effects will occur?
- When and where do effects occur?
- How confident are you, the RPM, in the conclusions of the risk assessment?
- What are the critical data gaps, and will information be available in the near future to fill these gaps?
- Is a refinement of the ERA required to reduce uncertainty and is it cost-effective?
- How could monitoring help evaluate results of the risk management decision?

NOTE: As stated earlier, most ERAs require no more than two tiers (the screening level and the baseline) to provide sufficient information to estimate risk.

When the ERA clearly indicates that unacceptable risk exists at the site, CERCLA requires a Feasibility Study to evaluate remedial alternatives. The analysis of alternatives compares various remedies to determine which has the most risk reduction within an acceptable time and cost framework. Other issues considered are the acceptability of the remedy to communities and the states, risks to the environment and public from implementation of the cleanup itself, and the long-term permanence of the remedy.

The importance of comparing existing site risk against physical destruction of the environment due to cleanup was shown by Hinckley and Porter [11] at a Midwestern site. They demonstrated that removal of lead from a wetland entailed destruction of the habitat, while only providing minimal reduction in hazard quotients for mice and raptors. Thus, they showed that

active remediation was not warranted. Comparing existing site risk against physical destruction of the environment due to cleanup is such an important part of the ERA process that the Navy has designated this as the Tier 3 of the Navy ERA process (see Section 3.4).

6. REFERENCES

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7. KEY TERMS

The following Key Terms are commonly used in Ecological Risk Assessments. Where applicable, a superscript identifies the reference(s) used to define the terms. These references are listed at the end of this section.

Abiotic:[1] Characterized by absence of life; abiotic materials include media such as water, soils, sediments; abiotic environmental parameters include light, temperature, pH, humidity, and other physical and chemical characteristics of abiotic media.

Accuracy:[1] The degree to which a measurement reflects the true value of a variable.

Acute:[1] Having a sudden onset or lasting a short time. An acute stimulus is severe enough to induce a response rapidly. The word acute can be used to define either the exposure or the response to an exposure (effect). Example: the duration of an acute aquatic toxicity test is generally 4 days or less, and mortality is the response usually measured.

Acute Response:[1] The response of (effect on) an organism that has a rapid onset. A commonly measured acute response in toxicity tests is mortality.

Acute Test:[1] A toxicity test of short duration relative to the life span of the test organism.

Assessment Endpoint:[1] An explicit expression of the environmental value that is to be protected.

Benthic Community:[1] The community of organisms dwelling at the bottom of a body of water.

Bioaccumulation:[2] The net accumulation of a chemical by an organism as a result of uptake from all routes of exposure.

Bioaccumulation Factor (BAF):[1] The ratio of the concentration of a contaminant in an organism to the concentration in the ambient environment at equilibrium.

Bioavailability:[1] The degree to which a material in environmental media can be assimilated by an organism.

Bioconcentration:[2] The net accumulation of a chemical directly from aqueous solution by an aquatic organism.

Biodegradation:[1] Decomposition into more elementary compounds by the action of living organisms, usually referring to microorganisms such as bacteria.

Biomagnification:[2] The tendency of some chemicals to accumulate to higher concentrations at higher levels in the food web through dietary accumulation.

Biomarker:[1] Biochemical, physiological and histological changes in organisms that can be used to estimate either exposure to chemicals or the effects of the exposure to chemicals. Caution: biomarkers may be induced by many man-made or natural stressors. When biomarkers are used, other indicators should be utilized to assure that the stressor causes the effects in question.

Biomonitoring:[1] Use of living organisms as "sensors" to detect changes in environmental conditions that might threaten living organisms in the environment.

Body Burden:[3] The amount of a substance that has accumulated in the tissue of an exposed organism, usually expressed as the concentration of the substance in a particular organ or in the whole organism.

Characterization of Ecological Effects:[1] A portion of the analysis phase of ecological risk assessment that evaluates the ability of a stressor to cause adverse effects under a particular set of circumstances.

Characterization of Exposure:[1] A portion of the analysis phase of ecological risk assessment that evaluates the interaction of the stressor with one or more ecological components. Exposure can be expressed as co-occurrence, or contact depending on the stressor and the ecological component involved.

Chemical (Contaminant, Constituent) of Potential Ecological Concern (COPEC):[1] A substance detected at a hazardous waste site that has the potential to affect ecological receptors adversely due to its concentration, distribution, and mode of toxicity.

Chronic:[1,2] Involving a stimulus or response that continues for a long time; often from several weeks to years, depending on the reproductive life cycle of the species (conventionally includes at least a tenth of the life span of a species). It can be used to define either the exposure or an effect. Chronic exposures typically induce a biological response of relatively slow progress and long duration.

Chronic Response:[1] The response of (or effect on) an organism to a chemical that is not immediately or directly lethal to the organism, but can affect long term health or survival of an organism. **Example:** Population decline of birds due to chronic exposure to DDT.

Chronic Toxicity Test:[3] A toxicity test that spans a significant portion of the life cycle of the test organism (e.g., 10% or more) and examines effects on such parameters as metabolism, growth, reproduction, and survival.

Community:[1,4] An assemblage of populations of different species within a specified location and time. It is a broad term that may be used to designate natural assemblages of different sizes (e.g., organisms inhabiting a rotting log, organisms inhabiting a vast forest or an ocean).

Concentration:[1] The relative amount of a substance in an environmental medium, expressed by relative mass (e.g. mg/kg), volume (ml/L), or number of units (e.g., parts per million (ppm)).

Concentration-Response Curve:[1] A curve describing the relationship between concentration and percent of the test population responding. Example: soil concentration of a contaminant versus percent earthworm mortality.

Conceptual Model:[1] A series of working hypotheses of how the stressor might affect ecological components. A description of an ecosystem or ecosystem components potentially at risk, and the relationships between Measurement and Assessment Endpoints and exposure scenarios.

Control:[1] A treatment in a toxicity test that duplicates all the conditions of exposure treatments but contains no test chemical. The control is used to determine the response rate expected in the test organism(s) in the absence of the test material.

Correlation:[1] An estimate of the degree to which two sets of variables vary together. Caution: High correlation between a stressor and the response of an organism does not necessarily mean cause and effect.

Deposition:[1] The dispersion of any material by natural processes such as wind or water or by lying, placing, or throwing down the material.

Depuration:[2] Loss of a material from an organism due to elimination and degradation.

Dose:[2] A measure of exposure. Examples: (1) the amount of chemical ingested. (2) the amount of chemical actually taken up or absorbed.

Dose-Response Curve:[1] A curve, plotted as Dose versus Response, that is similar to concentration-response curve except that the dose (i.e., the amount of chemical ingested, taken up, or absorbed) is known.

EC_x (Effective $Concentration_x$):[3] The concentration of a chemical that is estimated to cause a toxic effect on x% of test organisms. The duration of the exposure must be specified. Effects may be lethal or sublethal.

Ecological Component:[1] Any part of the ecosystem, including individuals, populations, communities, and the ecosystem itself.

Ecological Risk:[1] In the context of risk assessment, the expected frequency or probability of undesirable (or "unacceptable adverse") ecological effects resulting from exposure to known or expected stressors.

Ecological Risk Assessment: The qualitative or quantitative appraisal of the actual or potential impacts of stressors (i.e., contaminants) on plants and animals at a site, other than human and domesticated species.

Ecosystem:[1] The biotic community and abiotic environment within a specified location and time, including the chemical, physical and biological relationships among the biotic and abiotic components.

Ecotoxicology:[2] The study of toxic effects on non-human organisms, populations, and communities.

EEC (Estimated or Expected Exposure Point or Environmental Concentration):[1] The concentration of material estimated as being likely to occur in environmental media to which organisms are exposed.

Environmental Fate:[1] Disposition of a material in various environmental compartments (e.g., soil, sediment, water, air, biota) as a result of transport, transformation, and degradation.

Exposure:[1] Co-occurrence of, or contact between, a stressor and an ecological component. The contact reaction between a chemical and a biological system or organism.

Exposure Assessment:[1] The determination or estimation (qualitative or quantitative) of the magnitude, frequency, duration, and route of exposure.

Exposure Characterization: see Characterization of Exposure.

Exposure Pathway:[1] The course a chemical or physical agent travels from a source to an exposed organism. Each exposure pathway includes a source, an exposure point, and an exposure route. Transport/exposure media (i.e., air, water) also are included If the exposure point differs from the source.

Exposure Point[1]**:** A location of potential contact between an organism and a chemical or physical agent.

Exposure Profile: The exposure profile presents the concentration of the stressor and its distribution over time and space within the area of study. The exposure profile evaluates pathways and relates exposure or dose to Measurement Endpoints.

Food Chain:[1,3,4] The transfer of food energy from lower trophic level (see trophic level) to higher-trophic-level organisms that feed on them. A typical food chain structure consists of: producer (e.g., green plant) $\rightarrow$ primary consumer (e.g., herbivore {plant-eating animal}) $\rightarrow$ secondary consumers (consisting of smaller, then, at subsequent levels, larger carnivores {meat-eating animals}).

Food Web:[4] Many interlocked food chains (see food chain). Interdependent food chains that, taken together, represent the dependent feeding relationships of the organisms involved.

Forage Fish: Fish that are taken for consumption by higher trophic level organisms, during hunting or gathering by the organism.

Habitat:[1] Place where an organism lives.

Hazard:[2] A state that may result in an undesired event, the cause of risk. In environmental toxicology, the potential for exposure of organisms to chemicals at potentially toxic concentrations constitutes a hazard.

Hazard Assessment:[5] This term has been used to mean (1) evaluating the intrinsic effects of a stressor or (2) defining a margin of safety or quotient by comparing a toxicological effects concentration with an exposure estimate.

Hazard Index (HI):[1] The sum of more than one hazard quotient for multiple substances and/or multiple exposure pathways. The HI is calculated separately for chronic, sub-chronic, and acute exposures.

Hazard Quotient:[1] The ratio of an exposure level to a substance to a toxicity value selected for the risk assessment for that substance (e.g., LOAEL or NOAEL).

Home Range:[1] The area to which an animal confines its activities.

Hypothesis (pl. hypotheses): A set of tentative assumptions made in order to test their logical or empirical consequences.

Indirect Effect:[1] An effect where the stressor acts on supporting components of an organism (e.g., reproductive capacity) or of an ecosystem (e.g., habitat destruction), which in turn have an effect on the ecological component of interest.

LC_{50}:[2] Concentration of a substance that is estimated to be lethal to 50% of the test organisms over a specified period of time (see concentration).

LD_{50}:[2] The dose that causes mortality in 50% of the organisms tested (see dose)

Lethal:[1] Causing death by direct action.

Lowest Observed Effects Level or Concentration (LOEL or LOEC):[1,3] The lowest dose or concentration in a toxicity test or biological field survey that causes a statistically significant effect in comparison to the controls or reference site.

Lowest Observed Adverse Effect Level or Concentration (LOAEL or LOAEC):[1] The lowest dose or concentration in a toxicity test or biological field survey that causes a statistically significant adverse effect in comparison to the controls or reference site. The "adverse effect" should be clearly defined.

Measurement Endpoint:[5] A measurable ecological characteristic that is related to the valued characteristic chosen as the Assessment Endpoint.

Media:[1] Specific environmental compartments-air, water, soil-that are the subject of regulatory concern and activities.

Model:[2] A formal representation of some component of the world. Models may be mathematical, physical, or conceptual. Models used in environmental analysis range from mathematical simulations of ecosystem dynamics to statements that non-exceedence of a toxicological endpoint (e.g., EC_{50}) will adequately protect an exposed biotic community.

Model Error:[2] The component of uncertainty associated with a lack of correspondence between the model and the real world.

No Observed Effects Level or Concentration (NOEL or NOEC): The highest dose or concentration in a toxicity test or biological field survey not causing a statistically significant effect compared with controls.

No Observed Adverse Effects Level or Concentration (NOAEL or NOAEC): The highest dose or concentration in a toxicity test or biological field survey not causing a statistically significant adverse effect compared with controls. The "adverse effect" should be clearly defined.

Parameter:[1] Constants applied to a model that are obtained by theoretical calculation or measurements taken at another time and/or place, and are assumed to be appropriate for the time and place being studied.

Photolysis:[3] Decomposition or reaction of a substance caused by exposure to light.

Photosynthesis: The formation of carbohydrate by living organisms from carbon dioxide and water with the aid of light energy.

Piscivorous: Fish-eating.

Population:[1] An aggregate of individuals of a species within a specified location in space and time.

Probabilistic Risk Estimate: Probabilistic risk estimates are calculated by analysis of distributions of exposure and effects, rather than using single values. Risk is quantified by an expression of the overlap between the two distributions, with greater overlap indicating greater risk.

Reference Site:[2] A relatively uncontaminated site used for comparison to contaminated sites in environmental monitoring, often incorrectly referred to as a control.

Receptor:[5] The ecological entity exposed to the stressor (see stressor).

Replicate:[1] Multiple analyses of an individual sample. Replicate analyses are used for quality control.

Representative Samples:[1] Serving as a typical or characteristic sample; should provide analytical results that correspond with actual environmental quality or the condition experienced by the contaminant receptor.

Risk Assessor:[5] A professional who is knowledgeable and experienced in using the risk assessment process. This person is usually employed by the contractor at DoD sites.

Risk Characterization:[1] A phase of ecological risk assessment that integrates the results of the exposure and ecological effects analyses to evaluate the likelihood of adverse ecological effects associated with exposure to the stressor. The ecological significance of the adverse effects is

discussed, including consideration of the types and magnitudes of the effects, their patterns in time and space, and the likelihood of recovery.

Risk Manager:[5] An individual and/or organization that takes responsibility for, or has the ability to take action or require action, to mitigate risk.

Safety Factor:[2] A factor applied to an observed or estimated toxic concentration or dose to arrive at a criterion or standard that is considered safe.

Sediment:[3] Natural particulate matter that has been transported to, and deposited below, a body of water.

Sensitivity: The relative response of an organism to a toxic substance. Organisms that are more sensitive exhibit adverse (toxic) effects at lower exposure levels than organisms that are less sensitive.

Species:[1] A group of organisms that actually or potentially interbreed and are reproductively isolated from all other such groups; a taxonomic grouping in the category below genus.

Stress:[2] In the context of risk assessment, the proximate cause of an adverse effect on an organism or system.

Stressor:[1] Any physical, chemical, or biological entity that can induce an adverse response to an individual organism or to an ecosystem.

Stressor-Response Profile:[5] The product of characterization of ecological effects in the analysis phase of ecological risk assessment. The stressor-response profile summarizes the data on the effects of a stressor and the relationship of the data to the Assessment Endpoint.

Sublethal:[1] Below the concentration of a substance that directly causes death. Exposure to sublethal concentrations of a substance can produce less obvious effects on behavior, biochemical and/or physiological functions and the structure of cells and tissues in organisms.

Threshold Concentration:[1] A concentration above which some effect (or response) will be produced and below which it will not.

Toxicity:[2] (1) The harmful effects produced by exposure of an organism to a chemical. (2) The property of a chemical that causes harmful effects in organisms.

Toxicity Test:[1] An experimental procedure that estimates the toxicity of a chemical or other test material. A toxicity test is used to measure the degree of response produced by exposure to a specific level of stimulus (or concentration of chemical) compared with an unexposed control.

Toxicity Value:[1] A numerical expression of a substance's exposure-response relationship that is used in risk assessments.

Toxicant:[1] A poisonous substance.

Trophic Level:[5] A functional classification of taxa within a community that is based on feeding relationships (e.g., green plants make up the first trophic level, plant-eating animals make up the second, primary meat-eaters make up the third, animals that eat them make up the fourth, and so on). Note:[4] This trophic classification is one of function and not of species; a given species population may occupy one or more trophic levels according to the source of energy assimilated.

Uncertainty:[2] Imperfect knowledge concerning the present or future state of the system under consideration; a component of risk resulting from imperfect knowledge of the degree of hazard or of its pattern in space and time.

Uncertainty Factor:[2] A factor applied to an exposure or effects concentration or dose to correct for identified sources of uncertainty.

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[1] U.S. EPA. 1997. Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments. Interim Final, EPA 540-R-97-006; OSWER 9285.7-25; PB97-963211. U.S. Environmental Protection Agency Environmental Response Team, Edison, NJ.

[2] Suter, G.W., II. 1993. Ecological Risk Assessment. Lewis Publishers, Boca Raton, FL. 538 p.

[3] Environment Canada. 1997. Environmental Assessments of Priority Substances Under the Canadian Environmental Protection Act. Guidance Manual Version 1.0, EPS/2/CC/3E, Chemicals Evaluation Division, Commercial Chemicals Evaluation Branch, Environment Canada, Ottawa, Ontario, Canada.

[4] Daubenmire, R.F. 1974. Plants and Environment, a Textbook of Autecology. John Wiley and Sons, New York.

[5] U.S. EPA. 1998. Guidelines for Ecological Risk Assessment. EPA/630/R-95/002F. U.S. Environmental Protection Agency. Washington, D.C.

Appendix A: **Rules of Thumb for ERA.**

	RULE OF THUMB	PAGE
1.2	**Rule of Thumb #1:** Ecological Risk is **NOT** occurring if: ● The stressor is no longer present. ● The stressor did not/will not contact a susceptible ecological component. ● Contact with the stressor did not/will not occur long enough or in sufficient intensity (e.g., concentration) to cause a negative effect. Indirect effects (e.g., altered wildlife habitats) as well as direct effects should be considered.	**2**
1.2	**Rule of Thumb #2:** When no adverse ecological risk exists, the ERA should then stop, even if stressors (e.g., chemical compounds) are present. If land-use dictates that ecological components will not be present, the ERA should not proceed.	**2**
1.3	**Rule of Thumb #3:** Criteria for determining "adequate protection" and "unacceptable risks" should be decided by all persons responsible for site management and regulation before the ERA begins.	**3**
2.2	**Rule of Thumb #4:** Effectively utilize SMDPs (scientific/management decision points) in the risk management process.	**12**
4.2.6	**Rule of Thumb #5:** Bring all involved parties together early in the ERA process, to think through and come to agreement upon the Assessment Endpoints.	**23**
4.2.6	**Rule of Thumb #6:** Once the Assessment Endpoints are determined, they should remain unchanged throughout the ERA unless all parties agree to a necessary change or addition.	**23**
4.2.6	**Rule of Thumb #7:** For each Measurement Endpoint, RPMs should ask the risk assessor: ● What Assessment Endpoint does this Measurement Endpoint represent? ● What questions will be answered by the results of this test? ● What are the data criteria for judging whether the Assessment Endpoint has been met?	**24**

4.2.6	**Rule of Thumb #8:** If the ERA proceeds to the baseline level, the Measurement and Assessment Endpoints should change to become more site-specific.	**24**
4.2.8	**Rule of Thumb #9** Get regulator and stakeholder agreement on Assessment Endpoints, Conceptual Model, Measurement Endpoints, and Work Plan before proceeding with site investigation and risk characterization.	**26**
4.3.3	**Rule of Thumb #10:** If an Exposure Pathway is incomplete or does not exist, the pathway does not need to be evaluated further.	**28**
4.3.3	**Rule of Thumb #11:** A model is only as good as the information that goes into it. Model outputs are estimates that must be validated. They are not infallible.	**28**
4.3.4	**Rule of Thumb #12:** When choosing a reference location, make use of readily available scientific resources that have local site information.	**29**
4.3.4	**Rule of Thumb #13:** Potential "cause and effect" relationships between contaminants and the ecological Measurement Endpoints must be established; otherwise further assessment is not justified. Both direct (e.g., fish kills) and indirect (e.g., loss of habitat) effects must be considered.	**30**
4.3.5	**Rule of Thumb #14:** The RPM should keep track of the agreed-upon Assessment and Measurement Endpoints, plans, decision criteria, and approvals. Experience has shown that when pre-conceived notions of risk are not supported by site-specific evidence, involved parties (e.g., risk assessors, regulators, and environmental trustees) may suggest unplanned and possibly unnecessary studies.	**31**
4.4.2	**Rule of Thumb #15:** The RPM must ensure that the risk assessor derives realistic, site-specific Hazard Quotients (HQs), rather than simply applying generic, overly conservative values and excessive safety factors. In general, simple point estimates of risk such as HQs are most valuable as indicators of the need for further evaluation, not for defining risk management decisions.	**32**

APPENDIX B: List of Internet sites that contain information useful to RPMs responsible for overseeing Ecological Risk Assessments. Sites are listed by name, address, and content (information that can be obtained from the site). This is by no means a comprehensive list. The sites listed here also have links to other useful sites. Search for other sites related to ERA by applying key words such as "Ecological Risk Assessment", "ERA", "Environmental Assessment", and "Risk Management" and by using a search engine such as *Yahoo* or *Alta Vista*. Search for sites regularly.

Web Site	ADDRESS (HTTP://WWW.)	Content
Building Consensus Through Risk Assessment and Management of the Department of Energy's (DOE) Environmental Restoration Program	nap.edu/ readingroom/ books/doe/index.html	Results of a 1994 workshop consisting of DOE stakeholders and contractors to determine the feasibility and desirability of using risk assessment in the decision process.
Chemical and Biological Defense Information Analysis Center (CBIAC)	cbiac.apgea.army. mil	Information about the chemistry, toxicity, and fate of Chemical Warfare (CW) agent compounds and links to other DoD sites that have chemical fate and effects information.
Defense Technical Information Center (DTIC)	dtic.mil	DoD-related information including technical reports, studies and analyses, conference proceedings, journal articles, software, web links, etc. that may be useful to the ERA process.
DoD Environmental Cleanup Home Page	dtic.mil/envirodod/ index.html	Information about the DoD's Office of Environmental Cleanup and the Defense Environmental Restoration Program. Information about policy, contacts, public involvement, BRAC, publications, and related web sites is included.
Ecological Soil Screening Levels (ESSL)Workgroup	199.11.42.71/ecossl/ homepage.nff NOTE: Do not use the www prefix for this site	U.S. EPA, together with other Federal agencies, States, and industry groups, is developing a Guidance that will present eco soil screening levels (EcoSSLs) for 25 or so chemicals that are often found in soil at hazardous waste sites at levels that could pose an ecological risk. A technical support document will also be prepared presenting the data, models, equations, etc. and the rationale used to estimate these ESSLs. This information will be published as it becomes available.

Environmental Chemicals Data and Information Network (ECDIN)	agnic.org/agdb/ env_chem.html#top_txt	A wealth of information on the physical and chemical properties, production and use, legislation, toxicity, and environmental concentrations and fate of chemicals of actual or potential environmental significance.
Environmental Contaminants Encyclopedia	aqd.nps.gov/toxic/ index.html	This is a National Park Service document that provides free and unlimited use of environmental information on 118 toxic elements, petroleum products and compounds, PAHs, metals, cyanide, common VOC solvents, and BTEX compounds.
Extension TOXicology NETwork (EXTOXNET)	ace.orst.edu/info/ extoxnet	This site contains environmental chemistry, fate, and toxicological effects of pesticides. It is provided by the Cooperative Extension Service of several land-grant universities.
National Defense Center for Environmental Excellence (NDCEE)	ndcee.ctc.com/ index.htm	Resource for the development, application and dissemination of advanced environmental technologies. Results of these studies may be useful to RPM's when developing the scope of the ERA and for selecting remedial methods.
National Oceanic and Atmospheric Administration	noaa.gov	Links to a wealth of Oceanic and Atmospheric data and information.
National Resources Conservation Service (NRCS)	nrcs.usda.gov	The Technical Resources page at this site has links to web sites that provide extensive data and information on natural resources, soils, plants, and the Geographical Information Service (GIS). This information can be used for Exposure Characterization.
OSHWEB	turva.me.tut.fi/ ~oshweb	Many links to sites related to environmental and occupational health and safety.
Oak Ridge National Laboratory (ORNL) Ecological Risk Analysis: Tools and Applications	hsrd.ornl.gov/ ecorisk/ecorisk/ html	This site contains a lot of useful information for RPM's including Screening Benchmarks Database and related reports, ERA guidance documents, and links to related sites.

PubMed	ncbi.nlm.nih.gov	Free access to the National Library of Medicine's MedLine abstracts. This contains searchable abstracts of journal articles and books related mostly to human health risk, but information on food chain effects can also be found here.
Risk Assessment Resources on the World-wide Web	www.cantox environmental.com	This is a poster that was presented at the 20th annual meeting of the Society of Environmental Toxicology and Chemistry, Philadelphia, 1999. After entering the site, click on News. The poster contains a fairly comprehensive list of live links.
SciCentral	scicentral.com	Extensive gateway to over 50,000 sites in 120 disciplines pertaining to science and engineering. Many sites related to all aspects of ERA can be found here.
U.S. Environmental Protection Agency	epa.gov	Many publications are available through the National Center for Environmental Publications including *Framework for Ecological Risk Assessments*, *Ecological Risk Assessment Guidance for Superfund* (ERAGS), *Guidance for Ecological Risk Assessments*, and *Review of Ecological Assessment Case Studies*, Vols. I and II. Browse the catalog for documents pertaining to ERA. This site also provides updates on latest guidance, laws, regulations, and EPA policies as well as links to databases and software related to ERA.
U.S. Fish and Wildlife Service	fws.gov	Site information about freshwater and anadromous fish, migratory birds, endangered species, wetlands, conserving coastal areas, and environmental contaminants. The Endangered Species Act and data about listed species can be obtained from this site, free of charge.

U.S. Government Printing Office (USGPO)	access.gpo.gov/index.html	Access to free online federal databases including the Federal Register, the Code of Federal Regulations, and the Congressional Record, as well as the Catalog of U.S. Government Publications and the Government Locator Service. The EPA *Guidance for Ecological Risk Assessment* can be downloaded from this site.

APPENDIX C: Support Center Points of Contact and internet web site addresses of Department of Defense organizations that provide technical assistance for Ecological Risk Assessments.

SUPPORT CENTER POINTS OF CONTACT (POCs)		
Army	**Navy**	**Air Force**
Ms. Mary Ellen Maly US Army Environmental Center (AEC), Environmental Restoration Division Attn: SFIM-AEC-ERA Aberdeen Proving Ground, MD 21010-5401 COM 410-436-1511 DSN 584-1511 FAX 410-436-1548 maryellen.maly@aec.apgea.army.mil	**Ms. Ruth Owens** NFESC 1100 23rd Ave. Port Hueneme, CA 93043-4370 COM 805-982-4798 DSN 551-4798 FAX 805-982-4304 owensrw@nfesc.navy.mil	**Dr. Doris A. (Andy) Anders** Headquarters Air Force Center for Environmental Excellence (AFCEE) HQ AFCEE/ERC 3205 North Road Brooks AFB, TX 78235-5363 COM 210-536-5667 DSN 240-5667 FAX 210-536-5989 doris.anders@hqafcee.brooks.af.mil

Internet addresses of Department of Defense organizations that provide technical support for Ecological Risk Assessments.

Organization	INTERNET ADDRESS (HTTP://)
U.S. Air Force Institute for Environment, Safety, and Occupational Health Risk Analysis	sg-www.satx.disa.mil/~iera
U.S. Air Force Center for Environmental Excellence	www.afcee.brooks.af.mil
U.S. Army Center for Health Promotion and Preventive Medicine	chppm-www.apgea.army.mil
U.S. Army Corps of Engineers, HTRW CX	www.environmental.usace.army.mil
U.S. Army Environmental Center	aec.army.mil
U.S. Army Soldier and Biological Chemical Command	www.sbccom.apgea.army.mil
U.S. Army Waterways Experiment Station	www.wes.army.mil
U.S. Naval Facilities Engineering Command	www.navfac.navy.mil
U.S. Naval Facilities Engineering Service Center	www.nfesc.navy.mil
U.S. Navy Space and Warfare Systems Center (SPAWAR), Environmental Sciences Division	www.environ.spawar.navy.mil or environ.nosc.mil

Appendix D: This is a list of some databases available through libraries, universities, or private informational services that contain information on the properties, fate, and effect of chemical contaminants. Some of the following information services are available at no cost, while others may charge for their services.

1. Chemical Information System (CIS) - Chemical information databank - chemical and physical properties, handling and response, health effects, environmental effects. Daylight Chemical Information Systems Inc., 810 Gleneagles Street, Suite 300, Towson, MD 21286, USA. Tel: (410) 321-8440.

CERCLIS	CERCLA Information System – Information on hazardous waste site assessment and remediation from 1983 to present.
CHRIS	Chemical Hazard Response Information System - Physico-chemical properties and biological/fire hazard potential of over 1,000 substances for use in spill situations.
ECOTOX	Information on chemical-specific toxicity values in three U.S. EPA databases for aquatic life (AQUIRE), terrestrial plants (PHYTOTOX), and wildlife (TERRETOX).
ENVIROFATE	ENVIROnmental FATE - Physico-chemical properties and environmental transformation rates extracted from published literature on 800 substances.
ISHOW	Information System for Hazardous Organics in Water – Physico-chemical properties, fate, and effects of organic chemicals in water.
OHMTADS	Oil and Hazardous. Materials Tech. Assist. Data System - Physico-chemical and toxicological properties of 1,400 substances for use in hazard assessment.

2. National Library of Medicine's Database Selection Menu - National Library of Medicine 8600 Rockville Pike Bethesda, MD 20894 U.S. Toll Free:1-888-FINDNLM or 1-888-346-3656, email:tehip@the.nlm.nih.gov, URL:http://sis.nlm.nih.gov. Many of the databases listed below can be accessed, free of charge, via Internet Grateful Med (http://igm.nlm.nih.gov) and TOXNET Web Interface (http://toxnet.nlm.nih.gov).

DART	Developmental and Reproductive Toxicology - A bibliographic database covering teratology and other aspects of developmental and reproductive toxicology. It is a continuation of the ETICBACK (Environmental Teratology Information Center Backfile) database, which covers primarily teratology information published from 1950-1988. This database is also accessible through the TOXLINE® database (see below).
EMIC	Environmental Mutagen Information Center (1991 – present) and its backfile, EMICBACK® (1950-1991)- Bibliographic databases containing citations to literature on chemical, biological, and physical agents that have been tested for

genotoxic activity. These databases are produced by the Oak Ridge National Laboratory under the management of the National Library of Medicine (NLM).

HEAST — Health Effects Assessment Summary Tables - The HEAST is a comprehensive listing consisting almost entirely of PROVISIONAL RISK ASSESSMENT INFORMATION relative to oral and inhalation routes for chemicals of interest to Superfund, the Resource Conservation and Recovery Act (RCRA), and the EPA in general.

HSDB — Hazardous Substances Data Bank - Physico-chemical properties, ecotoxicity, environmental fate and behavior, safety and handling, legislation and analytical methods on over 4,000 substances.

IRIS — Integrated Risk Information System - U.S. EPA database containing summary health risk information on over 500 chemicals.

MEDLINE — MEDlars onLINE - National Library of Medicine's (NLM) premier bibliographic database covering the fields of medicine, nursing, dentistry, veterinary medicine, the health care system, and the preclinical sciences. Bibliographic citations (e.g., authors, title, and journal reference) and author abstracts from over 3,900 biomedical journals published in the United States and 70 foreign countries.

RTECS — Registry of Toxic Effects of Chemical Substances - An online file containing toxic effects data on over 130,000 chemicals. Both acute and chronic effects are covered including data on skin/eye irritation, carcinogenicity, mutagenicity, reproductive consequences, and multiple dose studies. Selected federal regulatory requirements and exposure levels are also presented.

TOXLINE® — Extensive collection of online bibliographic information covering the pharmacological, biochemical, physiological, and toxicological effects of drugs and other chemicals. TOXLINE and its backfile TOXLINE65 together contain more than 2.5 million citations, almost all with abstracts and/or indexing terms and CAS Registry Numbers.

3. Dialog Databases - References to and abstracts of articles from more than 100,000 international publications on science and technology, social sciences, and humanities. The complete text of articles from more than 7,000 journals, magazines, and newsletters. . A sampling of some of the databases that are relevant to Ecological Risk Assessment are shown below. The Dialog Corporation US Headquarters: 2440 W. El Camino Real, Mountain View, California, CA 94040-1400, Tel: (1)-650 254 7000 Fax: (1)-650-254-7070. Corporate Headquarters: The Communications Building, 48 Leicester Square, LONDON, WC2H 7DB, Tel: (44) 171 930 6900, Fax: (44) 171 930 6006

Aquatic Sciences and Fisheries Abstracts (ASFA) is a comprehensive database on the science, technology, and management of marine, brackishwater, and freshwater environments and resources. The database corresponds to the printed publications *Aquatic Sciences and Fisheries Abstracts*, Part 1: *Biological Sciences and Living Resources*; Part 2: *Ocean*

Technology, Policy, and Non-Living Resources; Part 3: *Aquatic Pollution and Environmental Quality*; *ASFA Aquaculture Abstracts*; and *ASFA Marine Biotechnology Abstracts*. The database also contains records that have not appeared in the ASFA print publications. It includes over 5,000 primary journals and a wide variety of other source documents including books, monographic series, conference proceedings, and technical research reports.

BIOSIS Previews® contains citations from *Biological Abstracts®* (BA), and *Biological Abstracts/Reports, Reviews, and Meetings®* (BA/RRM) (formerly *BioResearch Index®*), the major publications of BIOSIS®. Together, these publications constitute the major English-language service providing comprehensive worldwide coverage of research in the biological and biomedical sciences. *Biological Abstracts* includes approximately 350,000 accounts of original research yearly from nearly 6,000 primary journal and monograph titles. *Biological Abstracts/RRM* includes an additional 200,000+ citations a year from meeting abstracts, reviews, books, book chapters, notes, letters, selected institutional and government reports, and research communications.

CHEMTOX® Online database is a collection of environmental, health, and safety data for chemical substances that have properties that either cause them to be addressed by legislation or regulation, or make them potential candidates for legislation or regulation. Currently, CHEMTOX includes information on chemicals identified and regulated by the U.S. Environmental Protection Agency (EPA) under regulations such as the Resource Conservation and Recovery Act (RCRA), the Clean Air Act (CAA), the Clean Water Act (CWA), the Toxic Substances Control Act (TSCA), Superfund Amendments and Reauthorization Act (SARA), and Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA); the U.S. Department of Transportation (DOT) under the Hazardous Materials Transport Act; and the U.S. Occupational Safety and Health Administration (OSHA) under the Occupational Safety and Health Act. In addition, chemicals listed by the U.S. National Institute for Occupational Safety and Health (NIOSH) as workplace safety hazards and chemicals in the NIOSH Registry of Toxic Effects of Chemical Substances (RTECS) are included in CHEMTOX. Various lists of chemicals maintained by various agencies and governments are included in the CHEMTOX database. These lists include the carcinogens listed by the U.S. National Toxicology Program (NTP), the International Agency for Research on Cancer (IARC), and state lists provided by New Jersey, Pennsylvania, and California (Proposition 65). Chemicals listed under Canada's Workplace Hazardous Materials Information System (WHMIS) are also included in CHEMTOX.

Enviroline® covers the world's environmental related information. It provides indexing and abstracting coverage of more than 1,000 international primary and secondary publications reporting on all aspects of the environment. These publications highlight such fields as management, technology, planning, law, political science, economics, geology, biology, and chemistry as they relate to environmental issues. Enviroline corresponds to the print *Environment Abstracts*.

Environmental Bibliography provides access to the contents of periodicals dealing with the environment. Coverage includes periodicals on water, air, soil, and noise pollution; solid waste management; health hazards; urban planning; global warming; and many other specialized subjects of environmental consequence. The print equivalent is *Environmental Periodicals Bibliography*. More than 400 of the world's journals concerning the environment are scanned to create Environmental Bibliography. Journals represented are from the world's major publishers in science and technology (e.g., *Elsevier/Pergamon, Kluwer Academic, John Wiley & Sons,*

Blackwell, Plenum, and *Springer*), as well as from smaller publishers from many parts of the world. Many university press, society, and private publications are covered as well, some of which are available only on the Internet. Availability of the Web publications is noted in the Notes field, along with the relevant URL.

The Merck Index Online[SM] is the online version of the monographs in the printed 12th Edition of *The Merck Index* (a U.S. publication, Whitehouse Station, N.J., USA), an internationally recognized, one-volume encyclopedia of chemicals, drugs, and biologicals. Each monograph in the encyclopedia (each record in the database) discusses a single chemical entity or a small group of very closely-related compounds. Updates contain material not yet available in print. Records contain molecular formulas and weights, systematic chemical names (including CAS names), generic and trivial names, brand names and their associated companies, company codes, CAS Registry numbers, physical and toxicity data, therapeutic and commercial uses, and bibliographic citations to the chemical, biomedical, and patent literature.

Oceanic Abstracts organizes and indexes technical literature published worldwide on marine-related subjects. Over 9,000 citations from approximately 2,000 worldwide sources are added to the database each year. Records cite journals, books, technical reports, conference proceedings, and government and trade publications. Major subject areas covered by *Oceanic Abstracts* are oceanography, marine biology, marine pollution, ships and shipping, geology and geophysics, meteorology, and governmental and legal aspects of marine resources.

Pesticide Fact File (PFF), produced by The British Crop Protection Council (BCPC), is a factual data compilation on pesticides. PFF is the online version of *The Pesticide Manual*, which incorporates *The Agrochemicals Handbook*. The records in the database provide detailed scientific data on component active ingredients used in agrochemical formulation worldwide. PFF provides full nomenclature, physical and chemical properties, manufacturing companies, uses, product and residue analysis, mammalian toxicology, ecotoxicology and environmental fate information on the component active ingredients that are contained in agrochemical products (fungicides, herbicides, insecticides, etc.) used worldwide.

Pollution Abstracts is a leading resource for references to environmentally related literature on pollution, its sources, and its control. The following subjects are covered by the *Pollution Abstracts* database: air pollution, environmental quality, noise pollution, pesticides, radiation, solid wastes, and water pollution.

Water Resources Abstracts offers a comprehensive range of water-related topics in the life and physical sciences, as well as the engineering and legal aspects of the conservation, control, use, and management of water. The database, initiated in 1968, was produced by the U.S. Geological Survey, until 1994, and is now produced by Cambridge Scientific Abstracts.

Zoological Record Online®, produced by BIOSIS, provides extensive coverage of the world's zoological literature, with particular emphasis on systematic/taxonomic information. The database corresponds closely to the printed index, *Zoological Record*. The database includes thorough subject indexing in both controlled- and natural-language format. It also includes a unique systematics field, which gives complete taxonomic hierarchy information for most organisms discussed.

Appendix E: U.S. EPA Regional BTAG Coordinators/Contacts (as of 15 February, 2000)

EPA Region I
Patti Tyler
OEA
60 Westview St.
Lexington, MA 02421
781-860-4342
781-860-4397 FAX
tyler.patti@epa.gov

Cornell J. Rosiu
One Congress Street, Suite 1100
Boston, MA 02114-2023
617-918-1345
617-918-1291 FAX
rosiu.cornell@epa.gov

EPA Region II
Mindy Pensak
2890 Woodbridge Avenue
Bldg. #10
Edison, NJ 08837
732-321-6705
732-906-6824 FAX
pensak.mindy@epa.gov

EPA Region III
Jeff Tuttle
1650 Arch Street (3HS41)
Philadelphia, PA 19103-2029
215-814-3236
215-814-3015 FAX
tuttle.jeff@epa.gov

EPA Region IV
Lynn Wellman
61 Forsyth Street, SW 10th Floor (4WD-OTS)
Atlanta, GA 30303
404-562-8647
404-562-8628 FAX
wellman.lynn@epa.gov

EPA Region V
Brenda Jones/Jim Chapman
77 West Jackson Blvd.
Chicago, IL 60604
312-886-7188 Brenda
312-886-7195 Jim
312-886-4071 or 312-353-5541 FAX
jones.brenda@epa.gov
chapman.james@epa.gov

EPA Region VI
Jon Rauscher, PhD./Susan Roddy
1445 Ross Avenue - 12th Floor, Suite 1200
(6H-SR)
Dallas, TX 75202
214-665-8513 Jon
214-665-8518 Susan
214-665-6762 FAX
rauscher.jon@epa.gov
roddy.susan@epa.gov

EPA Region VII
Tom Lorenz/Bob Koke
901 N. 5th Street (SUPR/FFSE)
Kansas City, KS 66101
913-551-7292 Tom
913-551-7468 Bob
913-551-9468 FAX
lorenz.thomas@epa.gov
koke.robert@ epa.gov

EPA Region VIII
Gerry Henningsen, Ph.D./Dale Hoff, Ph.D.
999 18th Street, Suite 500 (8HWM-SM)
Denver, CO 80202
303-312-6673 Gerry
303-312-6690 Dale
303-312-6065 FAX
henningsen.gerry@epa.gov
hoff.dale@epa.gov

EPA Region IX
Clarence A. Callahan, Ph.D./Ned Black
75 Hawthorne Street
San Francisco, CA 94105
415-744-2314 Clarence
415-774-2354 Ned
415-744-1916 FAX
callaghan.clarence@epa.gov
black.ned@epa.gov

EPA Region X
Joe Goulet/Bruce Duncan Ph.D./Julius Nwosu
1200 6th Avenue (ES-098)
Seattle, WA 98101
206-553-6692 Joe
206-553-8086 Bruce
206-553-7121 Julius

206-553-0119 FAX
goulet.joe@ epa.gov
duncan.bruce@epa.gov
nwosu.julius@epa.gov

EPA Headquarters

David Charters/Mark Sprenger/Bethany Grohs
Environmental ResponseTeam
2890 Woodbridge Avenue, Building #18
Edison, NJ 08837
732-906-6825 David
732-906-6826 Mark
732-906-6168 Bethany
732-321-6724 FAX
charters.davidw@epa.gov
sprenger.mark@epa.gov
grohs.bethany@epa.gov

Steve Ells
HSED (5204G)
1200 Pennsylvania Avenue, N.W.
Washington, DC 20460
703-603-8822
703-603-9103 FAX
ells.steve@epa.gov

Appendix F: **Sources of Site Information. Organizations listed in this table may be contacted by calling their respective local phone numbers or accessing their internet sites (Appendix B)**

- Agricultural Experiment Stations (within university systems)
- National Oceanic and Atmospheric Administration (NOAA)
- National Park Service (NPS)
- Natural Resources Conservation Service (formerly U.S. Soil Conservation Service) (e.g., county soil surveys, natural resources inventories)
- Sierra Club (e.g., naturalist's guides)
- State Parks and Wildlife Departments
- U.S. Department of Agriculture (USDA) (e.g., Southern Forest Experiment Station, New Orleans, LA)
- U.S. EPA Environmental Research Laboratories
  U.S. Fish and Wildlife Service (USFWS)